

The SCIENTIFIC MONTHLY

January 1945

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THE SCIENTIFIC MONTHLY

JANUARY, 1945

THE MOST HOSPITABLE TREE

By ALEXANDER F. SKUTCH

WHILE yet an undergraduate in college, I was familiar with that remarkable work *Botanische Mittheilungen aus den Tropen*. In the nine slender volumes of this beautifully illustrated series of monographs, edited and in part written by the famous plant geographer A. F. W. Schimper, and published during the years 1888 to 1901, I became acquainted with some of the most fascinating phenomena of tropical botany: the adaptations of epiphytic plants, the strange modes of secondary thickening in the stems of woody vines, the complex relationships between ants and the plants that provide shelter for them, the fungus gardens of the leaf-cutting ants. Perhaps no other single work so strongly influenced my determination to devote some years to the firsthand study of tropical Nature—years that have stretched on and on to nearly two decades.

To the young student of Nature in the first exhilaration of his studies, no Sir John Mandeville or Marco Polo had filled his pages with more wonder-stories than were to be found in these records of sober scientific investigation. And perhaps the most marvelous of all the volumes, both in the patent drama of the situation described and in the agelong series of delicate adjustments and readjustments between organisms implied in the relationship, was the monograph by Schimper himself, on the *Cecropia* tree and its garrison of ants. Widely traveled, enthusiastic, keen-sighted, endowed in no small degree with the capacity for "the scientific use of the imagination," the author pointed out the features that made the tree a most favorable abode for the ants, providing them not only with commodious lodgings but also with a special and delicate food. In

return for food and housing, the hordes of little biting ants defended the tree against its enemies. Such, in brief, was Schimper's thesis, which, during many years' residence and travel in widely separated portions of the range of the *Cecropia* tree, I have had constantly in the back of my mind, so that observations, made deliberately or by chance, were classified according to whether they confirmed or refuted it. Will this story, which stirred the imagination of the young student, stand the test of a far longer familiarity with the *Cecropia* tree than its author himself enjoyed?

When at length I reached the Tropics, I was not long in recognizing the tree whose remarkable history I knew so well. Indeed, the genus *Cecropia*, of the mulberry family, contains the most distinctive trees of the New World Tropics. It comprises thirty to forty species, distributed not only over the entire length and breadth of the intertropical areas of the American continents but in the Antilles and other outlying islands as well. Were a wizard to drop a naturalist at random, blindfolded, somewhere within the vast sweep of the earth's central zone, no other single group of trees would so help him decide, by their presence or absence, whether he had been set down in the Western or the Eastern Hemisphere. For over its vast range, there is hardly a district with heavy or moderate rainfall where it is not abundant. It is absent only from desert and semidesert areas and from high mountains subject to nocturnal frosts. Yet in the equatorial Andes it grows abundantly up to an elevation of at least 8,500 feet, and in Central America to no less than 6,000 feet. Most common in the clearings and light second-



CECROPIA TREE, PANAMA

growth woodland, where frequently it is the dominant tree, it is by no means absent from primeval forest, often springing up in the little, light-flooded clear spaces left by the fall of a forest giant. Almost everywhere it is recognized and named by the country people. Throughout Central America it is called *guarumo*; in the montaña of Peru, *setico*; in the British West Indies, *trumpet tree*.

Not only wide range and abundance but also the ease with which the veriest novice in the forest can recognize them entitle the Cecropias to be considered the most characteristic trees of tropical America. In tropical forests, the leaf shape of scores and hundreds of kinds of trees is monotonous in the extreme—very different from the attractive variety of outline of the foliage of the oaks, maples, beeches, and chestnuts of a northern forest. Flowers are usually high out of reach, often inconspicuous, and to be had only at certain seasons and by the most adept climber; color and texture of bark sometimes lead the practiced eye to a correct identification, but they are not always to be relied upon. Familiarity with the trees of the tropical forest is to be gained only by long and arduous collecting, patient research, and much taxonomic skill. There are probably

not ten men alive who could correctly name at sight half the species of trees in an acre of well-developed virgin forest anywhere in the tropical lowlands of the American continents. How refreshing, then, to find a tree so distinct from all its neighbors, in foliage, bark, form, and half a dozen other well-marked characters that there is scarcely any possibility of confusion! Any intelligent lad from some far northern land, sent with only a written description to a tropical forest and told to bring back a specimen of a Cecropia tree, should be able to pick it out unaided and at first sight. I know no other tree of the tropical American forests for which I would hazard the same statement.

The Cecropias are small, medium-sized, or rarely (for the Tropics) tall trees, never attaining the height of the giants of the forest, nor ever remotely approaching them in the girth of their slender, graceful trunks. The bark is smooth, light gray, whitish, or greenish in color and prominently ringed, at intervals of a few inches, with narrow ridges—scars left by the fallen bud-sheaths. This smooth, light-colored, strongly ringed trunk alone serves to distinguish the Cecropia from nearly all its neighbors. At its very base, where it nears the ground, the trunk becomes slenderer instead of thicker; and the deficiency in girth and strength is counterbalanced by the presence of numerous prop roots, sometimes springing from the bole as high as 4 or 5 feet above the earth and descending obliquely until they enter the soil and ramify through it. Prop roots are not peculiar to the Cecropia—many other dicotyledonous trees, many palms, the pandanus, and even the maize plant have them—yet they will distinguish it from the vast majority of the trees among which it grows. The boughs of the Cecropia are coarse, stiff, and few in number, the lowest branches usually springing from the bole well above the ground. The branches are distributed in loose clusters, or false whorls, three to six together, with long stretches of branchless trunk between successive clusters. Like the trunk, the obliquely ascending boughs diminish little in thickness from base to top, and they bear few branchlets of the second order.

If the leaves were small, such a branch



THE BROAD, MANY-FINGERED FOLIAGE OF THE CECROPIA

system would produce a stiff and awkward tree; but on a well-developed *Cecropia* all suggestion of stiffness is prevented by the generous breadth and grace of carriage of the foliage. The ample leaves, sometimes a yard in diameter, are held in a more or less horizontal position at the end of yard-long, rounded stalks. They are peltate, roundish in outline, divided by deep and narrow indentations into long radiating lobes, and in some species silvery on the lower side, presenting a pleasing and characteristic aspect when tossed up by the wind. Rarely, as in *Cecropia araliaefolia* of the eastern foothills of the Andes, the lobing has been developed to the point where the leaves are divided into distinct, stalked leaflets, all radiating from the end of the long common stalk, like those of the horse-chestnut tree.

The flowers, minute and individually inconspicuous, seem unworthy of a tree with

such pronounced and individual characters. Yet in their arrangement they too are sufficiently distinctive. They are closely crowded in fingerlike aments, or catkins, in some species short and stubby, in others long and slender, sometimes twisted. These fingers are borne, in clusters of four or more, at the end of a common stalk, which may be short and stiff or long and pendulous. Male and female catkins are produced on separate trees, the former whitish and soon falling, the latter green and persistent, scarcely altering in appearance as their myriad florets swell into tiny one-seeded fruits. Each cluster of aments develops within a close-fitting sheath, which is white within and often has an attractive shade of pink or red on the exterior surface. This sheath splits along one side and drops when the flowers are ready to shed, or to receive, their pollen. It is the most colorful part of the tree.

A few words about the ecology of the *Cecropia* will help us to understand some of its peculiarities of form, especially its system of branching. It is a tree pre-eminently adapted for the colonization of denuded lands, whether these be a new clearing in the forest, an abandoned patch of cultivation, a flood plain along the shifting course of a great river, or the long, narrow band of raw earth streaked upon the mountain side by a landslide. On such areas tropical vegetation wears its most lush, most riotous and undisciplined aspect. The competition among the colonizers is exceedingly keen; the slow-growing seedling, although of the noblest lineage of the forest, has slight chance of success; victory—immediate victory, at least—favors the plant that can keep its "head and shoulders" above its rivals and so enjoy full exposure to the strength-giving sunlight. A wide-spreading, many-branched plant is likely to be smothered over and crushed down by a tangled mat of vines and creepers. The successful tree must not only grow rapidly in height, but it also must be sparing in the matter of breadth, hugging itself together lest it waste much-needed energy in horizontal expansion and give the eager, grasping vines a hold on itself. Such a tree is the *Cecropia*. Seemingly intent only upon outreaching its competitors, in crowded tangles it may attain a height of 20 or 30 feet, or even more, before it ventures to extend a single branch. Its ample leaves, each of which seems capable of the photosynthetic work of a whole spray of the smaller leaves of a northern plant, fall when their activity is taken over by younger leaves above them, thereby giving the creepers no permanent grasp upon the tree. So great is the heliotropism, or sunward impulse, of the vigorous young *Cecropia* that its slender stem is commonly dilated upward and, like scarcely any other tree, is thickest at the top, in the succulent green portion just below the apex. The inverted taper of the trunk is corrected in later life, when the tree has won the victory and spread its branches proudly above the rival vegetation, in part by secondary thickening, in part by the development of the stout prop roots at the base.

Such, then, are the appearance and mode of growth of the most highly individualistic

tree of the American Tropics. We have already discovered, in its very lineaments and most obvious outward vestiture, enough idiosyncrasies for any one tree. Yet we have scarcely begun to explore its peculiarities. Shake the branches of a *Cecropia*, and a host of small, brown or blackish ants comes swarming out through narrow, symmetrically placed orifices. They run hastily over bark and leaves and on to any object touching them, each biting with all its small might if it meets the body of an animal. Cut through the young stem or a branch with a single sharp blow of the machete, and the severed end reveals a central hollow, left by the almost complete breakdown of the pith, wider than in any other young woody stem I know. Or stand quietly watching a stem of one of the ant-inhabited species. A keen eye will soon notice that each of the long, hollow leaf stalks is swollen at the base, where it touches the stem, on the lower side, into an angular, kneelike protrusion, which is covered with brown hairs. After years devoted to the collection of tropical plants, handling thousands of species, I can recall no other tree with just such a leaf base. It would be remarkable enough without the little white bodies, each about the size and shape of a small ant's pupa, that stud it over, like little white-headed pins stuck up to the head in a brown velvet pincushion. Watching patiently, one may be fortunate enough to see an ant crawl over the cushion, touching with its antennae one after another of the little white beads, until it finds one that is ripe, plucks it off, and carries it into the hollow center of the branch through one of the small apertures. These, constituting the special food of the ants, are the protein bodies, often called Müllerian corpuscles in honor of their discoverer.

In harboring a colony of ants within its living tissues, the *Cecropia* is not unique in the vegetable kingdom. It belongs in a motley group known as the myrmecophilous, or ant-loving, plants. Like so many other natural phenomena, the *Cecropia* can be most intelligently understood if we consider it in relation to the class of objects of which it forms a part.

The myrmecophilous plants have only a single feature in common: the habitual oc-

currence of colonies of ants in hollow living organs, which, in many instances, appear to have been specially developed for the accommodation of the insects. All or nearly all these plants are of tropical distribution. As a rule a particular species of ant is found in each true myrmecophilous plant—and sometimes the ant is restricted to this peculiar habitat—suggesting that the myrmecophilous habit was developed in relation to this particular kind of guest and that the plant has not merely chanced to produce a hollow organ open to tenancy by the first small insect that happens by. The myrmecophilous plants are scattered sparingly through a considerable number of unrelated families—Rubiaceae, Piperaceae, Moraceae, Boraginaceae, Polygonaceae, Melastomaceae, Verbenaceae, Mimosaceae, etc.—indicating that they are not genetically related, but that the habit has developed independently in many distinct lines. The nature of the organs in which the insects are accommodated is as diverse as the families in which the myrmecophilous plants are classified. Perhaps the most common situation of the ant colony is in a stem left hollow by the breakdown of the central pith. Such ant-filled stems are found, in addition to the *Cecropia*, in the beautiful *palo santo* (*Triplaris*) and in certain arborescent species of *Piper*. In *Cordia alliodora* the insects find shelter in gall-like hollow nodes, situated at the point where several branches depart together from the end of a thicker twig. In certain tropical melastomes (*Tococa*) they dwell in paired hollow lobes at the base of the leaf blade, each with a narrow orifice on the lower side of the leaf. In some Central American species of *Piper* they establish themselves in the long, narrow hollow formed by stipules that have coalesced with the petiole, thence making their way into the stem and eating out the central pith. In the bull-horn acacias the ant colonies are established in the great, paired, hornlike hollow thorns, from which the curious little trees take their name. The hollows of the paired thorns intercommunicate at their base; and one thorn in each pair is provided by the ants with a small round aperture for going in and out. Perhaps the strangest of all the myrmecophilous plants are two epiphytic genera of the mad-



APEX OF A CECROPIA SHOOT

CUSHIONS AT PETIOLE BASES SHOWING PROTEIN CORPUSCLES; *left*, GROOVE AND PIT WHERE AZTECA ANTS GNAW; *top*, STIPULAR SHEATH FALLING AWAY.

der family, *Hydnophytum* and *Myrmecodia*, natives of the Indo-Malaysian area, whose curiously swollen stems are penetrated by a labyrinth of winding galleries in which the ants dwell. In eastern Costa Rica I found a species of polypody fern, not yet identified, whose slender stems, creeping over the mossy branches of trees, bear numerous brown gall-like bodies, about an inch in diameter, each with a doorway leading into a central hollow infested by tiny, stinging ants.

As a rule the host plant makes no special provision for the board of its lodgers. But in some instances the ants attend aphids that suck the juices of the plant, which thus indirectly provides for the support of its guests. Perhaps the most hospitable of all these myrmecophytes are our *Cecropia* and the bull-horn acacias, which provide a special food for their guests in the form of small, white protein corpuscles. In the *Cecropia* these tiny, many-celled corpuscles are, as we have seen, liberally produced, in successive crops, on the cushionlike base of each leaf stalk. In the acacia a single elongate, white food

partiele terminates each of the myriad little leaflets of the twice-compound leaf, and once it has been plucked away by the ants that dwell in the hollow thorns at the base of the leaf it is not replaced. The food-bodies of the acacia are sometimes called Beltian corpuscles, in honor of Thomas Belt, who first made them known to naturalists, just as Fritz Müller first described those of the *Cecropia*.

Of the ants regularly associated with these myrmecophilous plants, some are fierce and aggressive; but many are among the smallest, weakest, most defenseless and sluggish of their kind. They rarely if ever devour the foliage of their host plant or make indiscriminate attacks upon its living tissues. Some botanists believe that these ants benefit the plants in which they find shelter, by driving away foliage-eating insects, browsing mammals, and other enemies of vegetation. If this view be correct, the association between ant and plant is one of mutual benefit; the plant provides a lodging and sometimes also food for the ant, which in turn protects its host from attack. How true this is in the case of the *Cecropia* we shall now examine.

Of all ant-plants, except possibly the epiphytic myrmecophilous members of the mad-dler family, which I have never seen in their native haunts in the Oriental Tropics, the *Cecropia* appears to be the most highly specialized. In other words, it *seems* to have made a greater effort to attract its ant guests than any other of the ant-loving plants. Three unique features make it especially favorable as an abode of ants:

1. A remarkably wide central hollow in the stem. Hollow stems are commoner in herbaceous than in woody plants; but except the bamboos no other plant I know possesses, in undecayed young shoots, a central cavity so wide as this. Vigorous shoots often have a cavity fully two inches in diameter—surrounded by walls only about one-sixteenth of an inch thick—and this is to be found only a few inches below the growing tip of the shoot. With age the tissues immediately surrounding the cavity become hard and resistant. When old fallen trunks decay away, this is the last part of them to disappear. The hollow internodes, with their enclosing walls and transverse partitions, remain lying

on the ground like a chain of whitish, elongated, cylindrical boxes, or like the bleaching vertebrae of some huge ribless serpent.

2. The presence, in the wall surrounding the hollow that occupies each internode, of a pit, where the ants find it particularly easy to open a doorway. At the upper end of each of the short internodes, directly above the point of insertion of the leaf next below, is the small, somewhat elongate depression. The tissues separating the bottom of this pit from the central hollow are even thinner than the wall elsewhere; and they are composed of soft, thin-walled cells, vascular bundles being absent here. The ants find it easy to gnaw through the bottom of these pits; and in a tree inhabited by a flourishing colony, each one becomes the site of a doorway through which the insects pass in and out. Schimper laid special stress upon these pits, pointing out that they were present in the species of *Cecropia* habitually infested by ants but absent from those that had not developed the myrmecophilous habit. Similar pits are said to occur in the walls of hollow-stemmed plants of other genera not inhabited by ants, but they are certainly very rare. I have never seen any plant other than *Cecropia* with such pits.

3. The protein grains at the bases of the leaf stalks. Although such corpuscles, which are of the nature of glands, occur on other plants, some not ant-plants, they are very rare. The only other plants upon which I have seen similar protein corpuscles are the bull-horn acacias, with their hollow thorns inhabited by fiercely stinging ants. In the Old World Tropics they are said to be found on *Pterospermum javanicum*, where they are produced in tiny pitchers at the bases of the leaves; and on the long shoots of climbing species of *Gnetum*, which apparently do not attract ants.

Here, associated in the same tree, are three features—exceptionally wide central hollow, pits, and protein bodies—that although not unknown in plants not myrmecophilous are so rare that one might botanize through the Tropics for months or even years without finding—apart from *Cecropia*—any one of them singly. What, then, are the chances for a *random* association of the three in the same species? About as good, I should say,

as finding, while wandering through an uninhabited wilderness, an inn whose loosely closed door opened at a tap, and led to a table excellently spread, and a bed prepared for the weary traveler. It is easier to believe that the *Cecropia* has developed these three rare features not by chance—in the sense that they are unrelated—but rather through natural selection, because they are useful in making it an attractive home for the ants that protect it from its enemies. Such was Schimper's view. Let us see now how effective in guarding the tree the ants really are.

We may as well begin by considering the effectiveness of these Azteca ants in guarding their home tree against those creatures most destructive to vegetation—with shame I write it—man himself. As one of the abundant plants in the tall second-growth thickets, which in the Tropics are cut and burned to make fields for maize, rice, and other crops, the *Cecropia* is especially subject to attack by the long machete of the agricultural laborer. The garrison of ants serves not at all to protect the tree—and themselves—from destruction by his swinging blade; *Cecropia* trees are leveled indiscriminately with all the lush growth of giant herbs, bushes, vines, and other trees among which they form so conspicuous an element. The sweating laborer is indeed often bitten by the Azteca ants; but they are among the less formidable of the hosts of ants of many kinds and habitats whose bites and stings—along with those of a variety of other insects—are an inseparable accompaniment of his toil.

For the Aztecas can only *bite* with their mandibles. Their mode of attack is entirely mechanical; no venom is injected into the victim. Ants capable of inflicting really severe punishment *sting*, like honeybees, with the end of the abdomen, injecting a drop or so of formic acid. Neither biting ants nor biting bees—of which tropical America contains many kinds—command the same respect as their stinging relatives. I would rather endure the gnawings of a score of the *Cecropia*'s ants than one fierce sting of the long, slender ants that dwell in the bull-horn acacia, or, for that matter, of one of the tiny brown fire ants so annoyingly abundant about houses and lawns in tropical America. The Aztecas, weak and not particularly agile,



YOUNG CECROPIA SHOOT OPENED

REVEALING 11 INTERNODAL CHAMBERS, EACH ONE SURROUNDED BY THE WHITE REMNANTS OF CENTRAL PITH.

are seriously incommoded by hair no denser than that on the back of a man's wrist. A few of them biting away at the tough skin of a man's hands are of no great consequence. It is only on the tender skin of the neck and parts of the body habitually clothed that they cause much discomfort.

Cecropia trees are as a rule left unmolested by man, except when he is clearing land for sowing and other purposes, largely because they are of little use to him. Sometimes a segment is removed from a felled trunk, exposing the central hollow, which then serves as a gutter for conducting water—perhaps the only available substitute for a pipe in forest communities remote from both steel mills and native bamboos. The tough fiber in the bark is sometimes twisted into rope or used for making hammocks; but where the *burío* (*Heliconia*) or the *jucó* (*Trema*) are available, the *Cecropia* is rarely disturbed for this purpose. The choice is determined by the superior fiber of the first two, not by the ants in the last. Yet the botanist will admit that *Cecropia* trees are unpleasant plants to collect; if the ants are individually



THREE-TOED SLOTH (*BRADYPUS GRISEUS*)

IN PANAMA THIS ARBOREAL MAMMAL SOMETIMES COMPLETELY DENUDES CECROPIA TREES OF THEIR FOLIAGE.

not formidable, their very abundance is troublesome.

One has only to watch an Azteca ant struggling among the hairs of his forearm to suspect that on the body of a furry animal the insects would be as incapable of rapid and effective action as a man might be in the midst of the debris of a newly felled forest. Mammals of several kinds consume large quantities of the foliage of the *Cecropia*. The howling monkeys—those agile browsers of the tree tops—are fond of its great leaves and tender catkins; and in regions where they abound their vociferous bands are often seen among its branches. When first, in Panama, I studied Nature in the common range of the *Cecropia* and the howling monkey, I was reluctant to believe that the particular trees in which the monkeys foraged were indeed infested by ants. It seemed more likely—to one influenced by the writings of Schimper—that they had somehow escaped colonization by the Aztecas. I recall vividly how, years ago, I cut into the trunk of a tall *Cecropia*, whose growth in

girth had quite obliterated the lower of the ants' perforations for ingress and egress, while the howlers that had been feasting among its lofty branches shouted down their protests. But when I reached the hollow center the little Aztecas swarmed out; and I knew then that they were ineffective in guarding the tree against the depredations of the monkeys. These animals, it is true, devote a very considerable portion of their time to scratching themselves; but the amount of this activity bears no relation to the kind of tree in which they happen to be; and doubtless it is their own parasites rather than the Azteca ants that cause them discomfort.

Another tree-top browser very fond of the foliage of the *Cecropia* is the three-toed sloth (*Bradypus griseus*). This phlegmatic creature, whose existence appears so nearly vegetative, seems to have definite tastes in foliage. In western Panama, the sloths appear to prefer the *Cecropia* to other trees; just as in the highlands of Costa Rica the two-toed sloth (*Choloetis hoffmanni*) is found eating the

leaves of a certain tree (*Bruncellia costaricensis*) too often for it to be considered a mere matter of chance. Of five three-toed sloths that I saw in one day, while paddling along a lagoon in western Panama, four were in Cecropia trees. One of these, a female carrying her baby upon her breast, was descending the trunk of a Cecropia that had been defoliated to the last leaf. In eating, as in other activities, the sloth is quite as slow and deliberate as its name implies; a single large Cecropia leaf will engage its attention for half an hour or more; and a denuded tree indicates long and persistent activity by the beast. One might suppose that the Cecropia would produce leaves faster than a sloth could consume them. Like the monkeys, the sloth devotes a large share of its waking hours to scratching, with a steady, deliberate, mechanical action that scarcely reveals any trace of irritation or of feeling. But in this instance, too, the source of irritation appears to be other than the Azteca ants, which can scarcely find their way through the beast's coarse, dense pelage. When sated with its meal of foliage and finished with its scratching, the sluggish creature seeks the crotch of a stout limb, bends its head forward until its short, dull face is hidden between its forearms, and remains quietly sitting and slumbering upright in the fork, a featureless mass of gray hair, all oblivious of the ants that crawl over the limbs all around it.

Birds of many kinds visit the Cecropia tree, either to rest among its branches—where the ants appear never to molest them—or for more special purposes. The thick, green, fruiting catkins are a food attractive to fruit-eating birds as diverse as oropéndolas, toucans, barbets, cotingas, and finches, which help scatter the tiny seeds far and wide and are responsible for the far-flung distribution of the tree. In the upper Térraba Valley of Costa Rica, these catkins are probably the most important food of frugivorous birds during the early months of the year, when fruits of other sorts are scarce. Other birds, from big squirrel cuckoos to little wintering wood-warblers, seek the varied insects that thrive upon the succulent foliage. Although its coarse, open branch-system makes the Cecropia a poor site for

nesting, yet a few kinds of feathered creatures build their homes upon it and raise their families without molestation by the ants; just as birds of more numerous kinds place their nests in the bull-horn acacias, evidently taking advantage of the protection afforded by the fiercely stinging ants that dwell in the thorns. The bulky, domed nests of the chipsachery flycatcher (*Myiozetetes similis*) are not infrequently built in a crotch of a Cecropia tree.

Most of the feathered visitants to the Cecropia tree are beneficial, either in scattering its seeds or in removing insect pests. The theory that the Azteca ants are present as a standing guard of the tree would not require that they keep these birds away. But one bird that habitually frequents the Cecropia, and certainly does it more harm than good, is attracted by the ants themselves. The big pileated woodpecker (*Ceophloeus lineatus*), a black bird with a flamboyant scarlet crest, pierces young trunks and the slender branches with its powerful chisel-bill, to extract the ants and their pupae from the hollow center, now and again pausing in its work of perforation and extraction to pluck off great numbers of the unfortunate Aztecas that swarm over the bark. In widely scattered portions of its range, I have times without number watched this myrmecophagous woodpecker at its feast. These ants are an important constituent of the bird's diet. Like those other ant-eating members of the family, the flickers, the pileated woodpecker feeds its nestlings by regurgitation. This mode of bringing food to the nest is less prevalent among the New World woodpeckers than that of carrying it in the bill and has perhaps been developed in relation to the smallness of size of the individual particles that form the diet of those kinds subsisting largely upon ants. The holes made in the branches and young trunks of the Cecropia are closed at length by wound tissues that eventually form great tumorous protuberances; but many young trees break across at the point where they have been pierced low in the stem. Trees that have received much attention from the woodpeckers are less flourishing than their undisturbed neighbors, while their ant colonies are greatly depopulated. In regions



AN OROPÉNDOLA

THIS BIG COUSIN OF THE ORIOLES EATS THE FRUITING CATKIN OF CECROPIA. THIS IS A YOUNG BIRD.

where the woodpecker is abundant, it is incredible that the ants can be of sufficient service to the tree to compensate for the tremendous injury that their presence brings upon it.

To the pileated woodpecker the Cecropia is alluring in proportion to the number of ants it shelters; but to a number of small birds of quite different tastes it is most attractive when the Aztecas are few or absent. For only in the absence of the ants do the little white protein corpuscles become abundant and prominent on the furry cushions at the bases of the petioles; and when this occurs they offer a dainty food to a variety of small birds. I have watched twelve species take advantage of this food. The little, yellow-breasted Mexican honeycreeper (*Coereba mexicana*) is fond of these tidbits, which may form a not unimportant article in its diet. In parts of its vast range as distant as Costa Rica and Ecuador I have repeatedly seen the tiny bird pluck off the minute white bodies with the sharp tip of its strongly curved black bill. The Parula warbler of the Tropics (*Compsothlypis pitiayumi*) feasts upon these dainties; while such wintering members of the family as the Wilson warbler (*Wilsonia pusilla*), the Tennessee warbler (*Vermivora peregrina*), and even the thicket-

haunting mourning warbler (*Oporornis philadelphia*) have also discovered their secret. Among finches, the Mexican grassquit (*Tiaris olivacea*) and the seedeaters (*Sporophila* spp.) sometimes eat them; among tanagers, the euphonias (*Tanagra* spp.) and the blue-rumped tanager (*Calospiza gyroloides*); while in the highlands of Costa Rica the queer little ovenbird known as Lawrence's spinetail (*Acrorchilus erythrops*) consumes them in numbers. In this same region dwells the biggest bird that I have seen eat the protein bodies, the yellow-thighed sparrow (*Pseliophorus tibialis*), which is a finch as large as the towhee. In the excessively wet mountains where the spinetail and this sparrow dwell, the hollow stems of the Cecropia are much of the time flooded with water, with the result that they contain no ants to share the protein bodies with the birds. The visits of all these small birds are of no importance to the tree, nor do they help us to decide whether the Azteca ants form an effective guard; yet their presence is further evidence of the multiform bounty of the Cecropia.

But it is was not in defending their home tree against birds and four-footed animals, so much as against the depredations of other insects, that Schimper supposed the garrison of Azteca ants to be of greatest service. Yet frequently one sees a Cecropia with its foliage more or less damaged by leaf-eating insects. Sometimes the softer tissues of the great leaves are all but consumed by a budworm, even on trees with a thriving colony of ants. My own observations, made largely north of the Equator, are in full accord with those of Karl Fiebrig, who years ago, from studies made in Paraguay near the southern limit of the Cecropia's vast range, concluded that the ants were ineffectual in protecting the trees from a variety of insects and their larvae.

But in the Tropics perhaps no insects as a class are more injurious to vegetation than ants themselves. Abundant as these creatures are in the Temperate Zones, no one who has not actually lived in the tropical lowlands can form an adequate conception of their numbers and variety in regions of perpetual warmth. From crevices in the soil and the rocks to the topmost branches of the

great forest trees, they swarm everywhere in unbelievable variety and abundance. At times one's dwelling will be invaded by a horde of *Echiton*, or army ants, which flow like a stream through every nook and cranny, seeking out the small creatures of every kind on which they prey. These carnivorous legions perform their generally beneficial work of clearing the house of vermin and pass on; but smaller ants of various kinds are always present; and no food escapes their depredations unless stored in a sealed container or in a cabinet with legs set in water. The nests of these tropical ants are of the most astounding variety. Some are placed in the ground; some hang like great gray stalactites from the lofty boughs of trees; some occupy hollow dead branches; others are woven of finest silk secreted by the larval ants, among living foliage skillfully attached to the walls. It is not surprising that the hollow living organs of many species of plants should have been discovered and occupied by ants, which during the course of ages became specially adapted to life in these snug retreats, and in turn gradually produced changes in the structure of the host, thereby developing the curious phenomenon of myrmecophily.

The agriculturist in the Tropics wages a never-ceasing war against the battalions of the ants. They devour his seeds if germination is slow; they bite the young and tender tissues of plants, enlarge crevices in the bark of fruit trees for their nests, damage young sprouts by covering them with earth, spread mealy aphids over his sugarcane. Since turning attention to practical agriculture in the Tropics, I find it increasingly difficult to hold faith in Schimper's view that the extrafloral nectaries so common in the plants of warm regions are of service by attracting beneficial species of ants. I have never known a husbandman in tropical America who had a good word for the ants. Yet in the Orient the situation may be different. In Java the natives of certain districts collect, in the forest and among the trees along the seacoast, nests of a kind of large and fierce red ant, which they hang in their mango trees. Here the ants protect the developing fruits by devouring the larvae of a beetle (*Cryptorrhynchus mangifera*) capable of

causing great damage. The Javanese are said to attend these red ants with care, providing flesh to suit their carnivorous tastes, destroying other kinds of ants that are hostile to them, and joining the mango trees together by bridges of bamboo to facilitate the insects' visits to all parts of the grove. In ancient times the Chinese orchardists collected and propagated ants, which they placed in their orange and tangerine trees to keep them free of caterpillars. There was actually a special class of laborers who collected the ants.

But these husbandmen of the Far East never had to contend with the leaf-cutting *Attas*, which of all ants in tropical America do most conspicuous injury to vegetation. The nest of these brown spiny ants is made underground, and with time it becomes a far-flung labyrinth of chambers and intercommunicating tunnels, beneath the wide bare mound of earth thrown out during the course of their excavation. From the mound as a center, narrow, well-defined pathways, kept clean and bare of vegetation by the ants, extend far and wide over the neighboring terrain. Along these myrmecine highways a stream of ants is constantly flowing: huge-jawed, deliberately stalking soldiers, slender workers of medium size hurrying to their tasks, and tiny ants whose function is not at once apparent. Those traveling outward from the nest go unburdened; but in the returning stream a large proportion of the workers bear in their jaws pieces of green leaf far larger than themselves, rising above their backs like irregular standards or sunshades. Hence comes the name, parasol ants, sometimes applied to them.

Each bit of leaf is cut by the scissorlike mandibles of a worker ant from the foliage of a growing plant, whether tree, shrub, or herb. As it is borne along by the worker toward the nest, another smaller ant, or sometimes two or three together, may be seen clinging to the already huge burden and being carried toward the mound. Doubtless these riders are attempting to bear the burden themselves; but the strongest of those attached to the bit of leaf lifts the would-be helpers into the air and marches off with both cargo and assistants. Arrived at the nest, the pieces of leaf are carried into the

subterranean chambers and cut by the jaws of the ants into fine bits, which form a sort of compost heap, upon which a special kind of fungus is grown. The ants eat, not the leaf, but the fungus, which produces a profusion of minute, knoblike bodies in white, flocculent masses. It is supposed that the duty of the smallest class of workers is to weed the fungus gardens, removing all kinds of fungus growths except that upon which the population subsists. When they have served their purpose, the discolored bits of leaf, far from being eaten, are thrown out upon midden heaps near the entrances to the burrows.

Though these ants make use of the foliage of a great variety of plants native to tropical America—indeed, these were the only kinds available to them during the long centuries before Europeans, following Columbus, brought the products of the Old World to the New—some writers have thought they detected a special fondness for the leaves of cultivated species introduced from the Eastern Hemisphere. This seeming preference may be caused by the circumstance that in plantations, where little variety is within their reach, the Attas make severe attacks upon the dominant plant. A colony established in a lawn may almost defoliate the nearest ornamentals, whereas in the forest, with so many plants of so many kinds available, they show slight preference for particular species, and their injury to the vegetation is less evident. But it is certain that in many districts one cannot profitably grow his crops, or enjoy beautiful shrubbery and flowers about his dwelling, without waging unrelenting warfare against the leaf-cutters. Great coffee plantations employ squads of men for the sole purpose of destroying their nests, either by pumping poisonous gases into them or by digging them out, leaving great holes large enough to bury a yoke of oxen. The farmer may feel a bond of sympathy with these fellow agriculturists even as he proceeds to destroy them; but he knows very well that he and they cannot both make a living from the same farm.

Are the Azteca ants of the Cecropia tree an efficient guard against the destructive leaf-cutting Attas? Schimper believed that

they are. Examine a hundred Cecropias, even in a district where leaf-cutting ants abound, and few if any will show severe injury by them. But the same would be true of almost any other kind of tree, native or introduced, except in plantations and door-yards where the bare soil invites the establishment of Atta colonies, and they have little variety of vegetation to choose from. Rarely the Atta ants make great inroads upon the foliage of a Cecropia, cutting away the great leaves until only the principal veins remain, each margined by a narrow strip of tissue with circular indentations that reveal the ants' mode of work. I have seen such depredations on Cecropias that supported a flourishing colony of Aztecas.

For several months I have been looking for a Cecropia that gave evidence of the work of the Attas, but without success. This might be construed to favor the theory of mutual protection; but I have also failed to see the leaf-cutting ants at work upon a *burio* (*Heliocarpus*), a soft-wooded, swift-growing tree of the same habitat as the Cecropia and no less abundant, but with solid stems that provide no accommodation for ants. The Attas are happily not very abundant in this district—except in our canefield.

Finally, in order to witness what would happen when Atta and Azteca came face to face, I captured a few leaf-cutting ants and placed them upon the stem of a young Cecropia tree. The occupants were mostly indoors; and the unintentional trespassers wandered aimlessly about without meeting them; so I shook the sapling to bring the Aztecas outside. The little ants came pouring out their narrow doorways and raced about over stem and leaves, as if seeking the cause of the disturbance. Many of them passed close by the Attas; and often they ran beneath the longer-legged brown ants, without paying any attention to them. This might happen a number of times, and the interlopers remain for several minutes unchallenged in the midst of the swarming Aztecas. But sooner or later an Azteca would seize an Atta by a leg, or more rarely the body, and then one of several things might happen. Sometimes, in a manner difficult to understand, the tiny Azteca

would throw the big Atta from the tree, retaining its own hold. Far oftener the tussle would continue until the unequal adversaries fell, clutched together, to the ground. Or, if the struggle was long-drawn-out, other Aztecas, bumping into the contestants, would join the fray. Although many of the smaller ants might brush against an undisturbed Atta and pass on, every one that came within touching distance of an ant already attacked would at once seize upon it. Soon the unfortunate leaf-cutter would be in the midst of half a dozen angry little Aztecas, pulling out its long legs this way and that, biting its hard brown body, until at length the whole writhing mass fell from the tree. Some of the Attas, especially the larger workers, easily repelled each attacking Azteca with a single nip of their powerful mandibles and went wandering around until they reached the ground.

The same was true of some large black ants with golden abdomens that I found on the *Cecropia* trees—the Aztecas were helpless against their strong jaws. There is no doubt that the *Cecropia* tree's garrison of ants attempts to repulse invading ants, in many instances with success. But if they are not stirred up, as in my experiments, a foreign ant might wander far over the tree without meeting a defender; and the latter often proves entirely neutral when at last contact is made. The Attas placed one by one upon the *Cecropia* were lost, aimless, far outnumbered. From what I saw it was not difficult to picture a whole organized column of them mounting the trunk of an otherwise undisturbed *Cecropia* and cutting the leaves, without meeting real resistance from the supposed garrison. But resistance or no resistance, they are quite capable of carrying

off the foliage of a well-populated tree when they want it.

Monkeys, sloths, woodpeckers, honeycreepers, and many other birds, Azteca ants, leaf-eating insects, and at times even Atta ants—are they not all in the same category, guests that come to partake of the bounty spread for them by the most hospitable tree of the Tropics? Some do it harm by stripping it of foliage or drilling holes in its trunk; others, as the small birds that eat the protein bodies, and apparently also the Azteca ants themselves, appear neither beneficial nor directly harmful; only the larger fruit-eating birds that scatter its seeds far and wide, and the insectivorous species that remove caterpillars from the leaves, are an undoubted positive benefit. The Aztecas, instead of a formidable guard to repel all intruders from an inhospitable tree, may be simply the foremost beneficiaries of a bountiful one.

But the admission that the most distinctive is also the most hospitable tree of tropical America forces us to concede it still a third superlative. For to deny that the ants are of positive benefit to the tree is to refute the only plausible explanation that has been advanced for the evolution of its three great structural peculiarities: the exceptionally wide central hollow of the stem, the furry protruding leaf bases with their protein bodies, and the pits that facilitate the perforation of the wall surrounding the hollow internode. Without some single use to which all three contribute, how can we account for the presence in a single species of features that would be surprising enough as random developments in three different families? The mystery still challenges us. The *Cecropia* is the most enigmatic tree of tropical America.

FBI LABORATORY IN WARTIME

By JOHN EDGAR HOOVER

CHEMISTRY, physics, and mathematics in their myriad subdivisions and applications have played a highly important role in carrying out the duties imposed upon the Federal Bureau of Investigation by the President's Directive of September 6, 1939, requesting it to take charge of and to correlate the investigative work in all matters relating to espionage, sabotage, and subversive activities.

The responsibility of maintaining the internal security of our country increased tremendously the volume of scientific work flowing into the FBI Laboratory from federal, state, county, and local law enforcement agencies. In the fiscal year ending July 1, 1940, the Laboratory conducted 7,097 examinations involving 39,500 specimens of evidence, whereas in the fiscal year ending July 1, 1944, there were 154,511 examinations and 223,048 specimens of evidence. These figures represent an increase of 2,200 per cent in the number of laboratory examinations performed.

The present war naturally has wrought great changes in both the industrial and scientific fields. The spectrograph, which for many years was used primarily as a means for providing additional data relating to astronomical phenomena, is now providing both qualitative and quantitative control of the composition of materials vital to the proper and adequate functioning of our war machine. The control of the compositions of alloys such as steels, duralumin, and magnalium is now being monitored spectrographically at the furnaces of our industrial plants, thus eliminating time-consuming analytical chemical procedures previously employed.

Spectrographic techniques have been employed in the FBI's Laboratory for many years, and as a result unusual and novel methods of handling and analyzing minute quantities of evidence have been developed. Unfortunately the qualitative and quantitative procedures for analyzing metals in the industrial field cannot be universally employed in the crime detection laboratory, where the examiner cannot control the quan-

tity, shape, and contaminants of his specimens. In the crime laboratory each specimen of material is different from the one that preceded it.

The light radiated when a specimen of material is burned can be readily analyzed spectrographically, and permanent photographic records produced of the chemical constituents of the material burned. In some cases in which the quantity of evidence is extremely small the entire specimen must, of necessity, be burned and destroyed. In such instances the spectrographic plate becomes the only record of the evidence in the case.



A SPECTROGRAPH EXAMINATION
IN THE FBI LABORATORY, DEPARTMENT OF JUSTICE.

The spectrographic technique is limited by certain factors; namely, the quantity of light radiated while the specimen is burning, the light absorbing qualities of the mediums through which the light must pass, the dispersing power of the prism or the grating used in the instrument, and the speed and physical properties of the photographic medium. Fortunately even microscopic particles radiate ample ultraviolet, visible, and

infrared light to be recorded spectrographically.

Foreign metal fragments found on the cutting edges of tools used as implements of sabotage or spite grievances have been successfully identified with damaged material. In one instance it was possible to identify numerous fragments of glass found in the hydraulic systems of fighter planes as having come from a glass pressure gauge of the hydraulic testing unit in the manufacturing plant. Additional investigation showed that an industrial accident was involved, and not a premeditated act or foreign-directed sabotage.

The use of this equipment has also increased the percentage of solutions of automobile hit-and-run cases. Usually the scene of such an accident lacks obvious clues and evidence, but the searching eye of a thorough investigator seeks out minute particles of evidence, which, small and insignificant as they may at first appear, can become very important clues when submitted to scientific methods of identification and comparison.

Recently a National Automotive Paint File was established in the Spectrographic Section of the Laboratory. Here are maintained specimens and specifications of automobile paints for commercial and private cars, as well as for cars and other mobile units of the armed services. The file is most valuable in assisting the technician to show that the small fragments of paint found at the scene of the accident or on the victim's clothes or motor vehicle came originally from a car of a certain make manufactured in a particular year. By the application of microscopic, microchemical, and spectrographic techniques on a few paint particles, several cases involving the collision of military vehicles, as well as innumerable hit-and-run cases wherein private cars have been involved, have been solved through reference to this file.

X rays have made an invaluable contribution to the FBI Laboratory, particularly in the analyses of defectively and fraudulently prepared material for use in the country's war machine. Castings of airplane parts manufactured by one aluminum company failed to meet specifications relative to their chemical constituents and were welded to



APPLICATION OF X RAYS
PREPARING A CASTING FOR EXAMINATION BY X RAYS.

shield defects. The evidence developed from X-ray photographs, which were made in the Laboratory, was of considerable assistance in the prosecution of the parties involved.

Intermediate between the useful energies of X rays and the energies of visible light is the ultraviolet portion of the light spectrum. This region finds application in the detection of secret writing, a tool of espionage agents and saboteurs. Many chemicals that appear colorless and invisible in sunlight or artificial white light may become visible when exposed to ultraviolet light because of their phosphorescent and fluorescent properties. After ultraviolet irradiation phosphorescent materials radiate visible light for a period of time dependent on the period of excitation and the character of the substance, whereas fluorescent materials radiate visible light only as long as the ultraviolet rays are directed on the material.

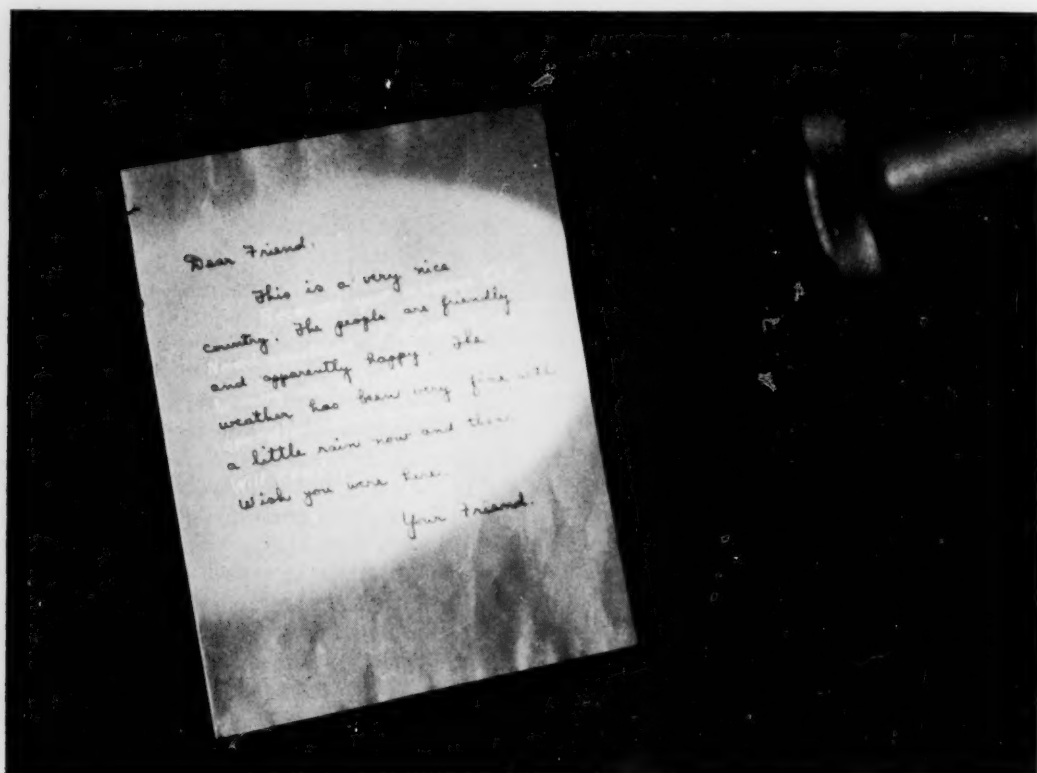
Laboratory work in connection with the landing of the eight Nazi saboteurs on the Amagansett shores of Long Island and in Florida in June of 1942 illustrates this type of investigation. Among the numerous articles furnished by their German superiors were boxes of matches tipped with quinine for use in sending invisible secret messages. A message written with such an implement

could be read simply by treating the document with a dilute acid and viewing the material under the ultraviolet light. The chemical action of the acid produces a different compound that fluoresces and radiates visible light.

From X rays and the ultraviolet one passes through the visible colors in the sun's spectrum into another region of invisible light called infrared. This has been employed extensively by the armed forces in aerial pho-

ties of surfaces and solutions yield information relative to their composition and physical properties. This region of the electromagnetic spectrum has recently made possible a new spectrophotometric technique for the identification of small quantities and mixtures of complicated organic compounds.

In addition to the spectrograph and the spectrophotometer, the FBI Laboratory is equipped with a densitometer. This instrument is a photoelectric unit for determining



AN EXAMPLE OF SECRET WRITING

REVEALED BY USE OF ULTRAVIOLET LIGHT IN THE FBI LABORATORY, DEPARTMENT OF JUSTICE, WASHINGTON, D. C.

tography because of its ability to penetrate hazy atmospheres and reveal camouflaged buildings and equipment. Owing to these same properties, infrared light is of value in the restoration of altered and forged documents in the Laboratory. It also has applications in infrared burglar alarms and blackout photography, which employs flash bulbs that radiate only infrared light. With the use of an infrared spectrophotometer, the infrared reflection and transmission proper-

ties of the spectral lines appearing on the photographs that are made in the spectrograph. The density of the spectrographic lines is a quantitative measure of the constituents of the material burned. A second photoelectric unit called an opacimeter is also available for determining the opacity of papers and similar reflecting surfaces.

Electricity is equally as important as optics in the FBI Laboratory. Electroanalyzers for rapid chemical determinations,

electrometric pH equipment, and the Magnaflux represent some of the electrical instruments. The Magnaflux is used to determine the presence of surface cracks and defects in magnetic metallic objects. If a magnetizable object, such as an iron bolt, is placed in a magnetic field created by the instrument, the field distributes itself throughout the metal provided it is sound. If cracks and discontinuities are present, however, magnetizable pigments orientated around the breaks indicate their location. This equipment is of inestimable value in conducting some metallurgical examinations.

Metallurgy itself figures significantly in analyses involving cases of real or suspected sabotage. Fractured machine parts, dismembered cables, and metallic fragments of a foreign nature found in the lubricating systems, bearings, and other moving parts of machinery are typical of the evidence received in the FBI Laboratory for metallurgical analysis. In analyzing a particular specimen and comparing it with other specimens, cross and longitudinal sections are so mounted that their crystalline structures may be observed under a metallurgical microscope. Thus the similarities or dissimilarities between specimens may be revealed. In addition, the nature of the industrial treatments initially employed in the manufacture of the specimens as well as the functions the specimens were made to perform as component parts of a machine may be evident to the metallurgist.

A case depicting the part metallurgical examinations are playing in security work involves a tractor that was manufactured in a plant in the Middle West and exported to Melbourne, Australia. When it was received in that city, a large deposit of fine iron granules was found in the oil pan. The tractor's timing gear, crankshaft, and bearings had been ruined by the granules, and it was believed that an act of sabotage could have been committed. A quantity of similar metal was discovered around the oil level gauge sleeve of the tractor, adhering under paint which had hardened. Inasmuch as the paint had been applied in the United States, these granules must have been present prior to the exportation of the vehicle. The tractor was of the type that some foreign governments



A COMPARISON MICROSCOPE
BEING ADJUSTED FOR EXAMINATION OF EVIDENCE.

have converted into armored tanks for military purposes. A metallurgical examination was made, and the samples were revealed to be white cast iron. The polished sections of these specimens revealed them to be composed of cementite and pearlite with no graphite plates such as occur in gray cast iron. White cast iron is extremely hard and brittle, and because of this hardness it was suggested that it may possibly have been used as an abrasive. Further investigation utilizing the leads revealed by the laboratory examination brought the case to a logical conclusion.

Petrographers in the FBI Laboratory who handle analyses of abrasives, minerals, and soils employ many of the principles of the physical sciences in the determination of the optical and physical characteristics of these materials. Through use of the petrographic microscope, polarized light, and the refractometer the refractive, axial, and the polarizing properties of crystals, the crystalline form, if any, and the cleavage of the substance being examined can be determined optically. Consequently, in scientific criminal examinations of this type in which comparisons of the samples are desired, a great significance is attributed to the optical properties that are observed by the petrogra-

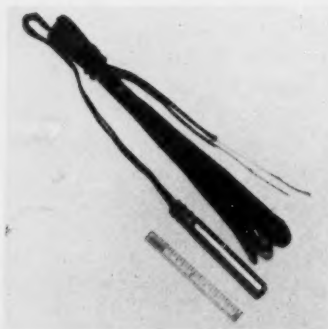
pher. To assure high accuracy in the determination of the indices of refraction of particles of soils, crystals, minerals, or glass, a double variation method may be employed. This utilizes two methods of varying the index of a liquid, changing the temperature of the comparison-standard refracting oil, and changing the wave length of the light used as an illuminating source.

In many petrographic analyses, specimens of oils and grease are examined in order to determine whether foreign materials or abrasives are present. An oil cup containing oil or the catch-pan from the disrupted piece of machinery might be submitted for examination. The foreign materials present are first separated from the oil by centrifuging, and the residue is then analyzed to determine the abrasive nature of the material. Mechanical separations are made by sifting and by sedimental procedures employing differences in

the specific gravity of the constituent parts of the foreign materials. The abrasives thus recovered may be compared with known abrasives that are maintained in the Laboratory in the Standard Abrasives File or with abrasives obtained from particular sources. By this method it is often possible to localize the source of the contamination and the destruction.

On one occasion the Laboratory received one quart of lubricating oil taken from the oil system of a steam turbine, and it was believed that an act of sabotage had been committed by the inclusion of abrasive material in the unit. The specimen of oil was found to contain considerable foreign contaminants, which were removed in the Laboratory and identified as silicon carbide abrasive consisting of crystals and crystal fragments varying greatly in size and shape. The abrasive was unusual in that it was not derived from

FEDERAL BUREAU OF INVESTIGATION
UNITED STATES DEPARTMENT OF JUSTICE
J. EDGAR HOOVER, DIRECTOR



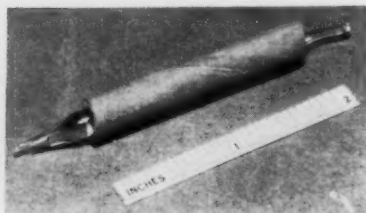
ELECTRIC BLASTING CAP WITH
COPPER WIRES



SAFETY FUSE LIGHTER FOR THE IGNITION
OF STANDARD SAFETY FUSE



ELECTRIC MATCH WITH SCREW CAP REMOVED—USED IN
CONJUNCTION WITH TIMING MECHANISM AND BATTERY



CAPSULE CONTAINING SULPHURIC ACID ENCASED
IN RUBBER TUBING FOR PROTECTION



THE CASE OF THE EIGHT GERMAN SABOTEURS



THE CASE OF THE EIGHT GERMAN SABOTEURS

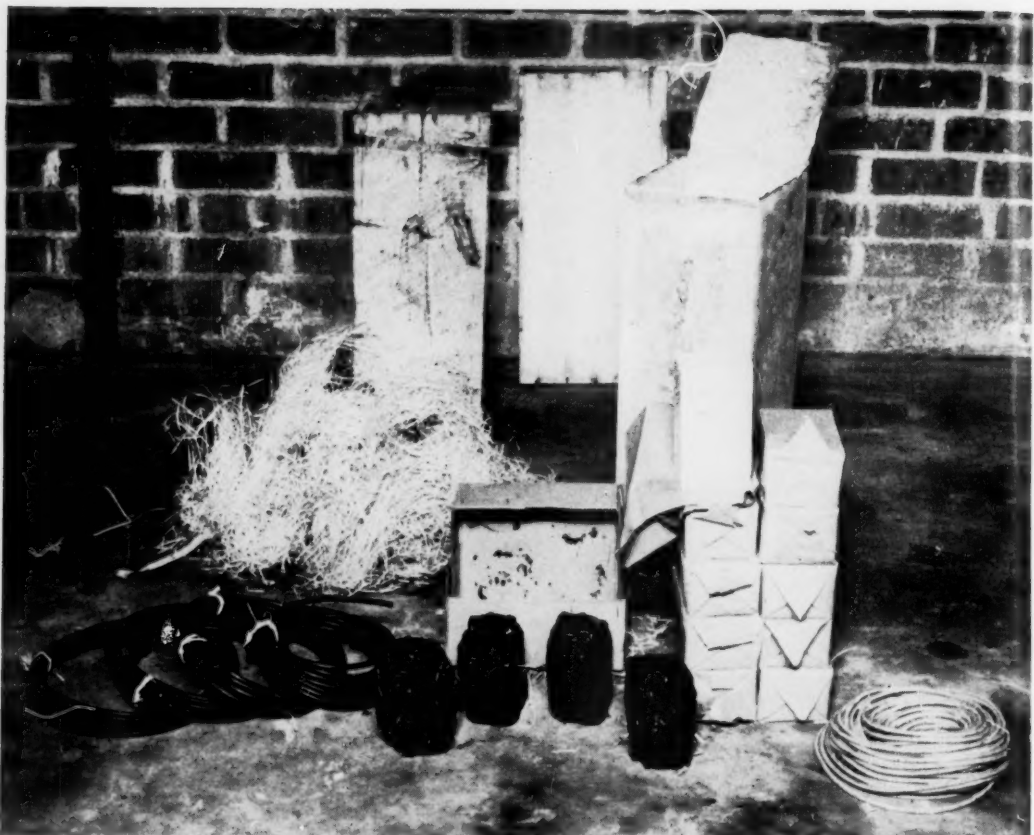
ELECTRIC BLASTING CAPS, PEN AND PENCIL DELAY MECHANISMS, DETONATORS, AMPOULES OF ACID, ET CETERA.

a grinding wheel or a grinding compound but from some process similar to a sand blasting method employed in the surfacing of metals. Further investigation by Agents of the FBI uncovered similar specimens of abrasives that led to the successful solution of the case.

Chemical tests of various types likewise play a major role in the wartime work of the FBI Laboratory. Many examinations result from the destruction of or damage to war goods by acids or other chemicals. To determine the nature of the chemical employed and to observe the nature of the surface destruction require unlimited effort and acute and persistent observation.

Another type of case which has come to the attention of the Laboratory since the advent of the war involves violations of the Selective Service Act by individuals attempting to avoid being drafted. In Los Angeles, Cali-

fornia, a radio repair shop owner notified the FBI that he had been contacted by the owner of a firm that produced pills and tablets. The vendor advised him that he could be provided with tablets that would "fluff up" his heart and as a result make him unfit for military service. Accompanied by an Agent of the FBI, the radio man contacted the pill manufacturer, and the two received pills, which according to the Laboratory analysis contained thyroid, pituitary, and prostate extract. Nine of the tablets were to be taken each day so that there would be no question of rejection at the Army Induction Station. At the time of contact the owner of the firm mentioned that he had helped numerous others to evade service in this manner. He was brought to trial on June 28, 1944, and convicted on the strength of the laboratory examination and other testimony. The evidence completely contra-



THE CASE OF THE EIGHT GERMAN SABOTEURS

CONTENTS OF BOX: SAFETY FUSE, DETONATING FUSE, TEN BLOCKS OF TNT, AND FOUR BOMBS RESEMBLING COAL.

dicted the contention that the pills were composed of vitamin B₁.

Examinations involving the analyses of firearms, toolmarks, explosives, and incendiaries in the FBI Laboratory frequently are directly connected with the war effort. The case of the eight Nazi saboteurs represents a cross section of this type of work. The major portion of the equipment carried by these individuals was of a destructive nature and included such articles as demolition blocks, brass and plastic relay devices, fuse lighters, blasting caps, pen and pencil incendiary sets, electric match heads, safety fuse and detonating fuse, as well as numerous other articles including some glass ampoules containing powders of unknown composition. The determination of the constituents of

these explosives and their uses, effects, and operation required a large number of detailed analyses.

The magnitude of the application of the sciences in the FBI Laboratory can be appreciated when it is realized that thousands of examinations are conducted each month. Laboratory analyses and field investigations both indicate that there has been no successful foreign-directed sabotage to date. From January 1, 1940 to September 1, 1944, 17,060 cases of reported sabotage were investigated by the FBI. While sabotage of some form was found in 1,837 instances, the vast majority of the acts were due to spite, carelessness, and similar reasons. As of September 1, 1944, a total of 542 convictions resulted from prosecutions in the courts.

THE RUHR

By CHAUNCY D. HARRIS

THE use to which the Ruhr is put after this war may determine the character and duration of peace in the next generation. Located near the Netherlands boundary, this German district is of world concern primarily as the greatest center of steel and coal production in the Eastern Hemisphere (Fig. 1). It is a factor in many proposals for the postwar treatment of Germany. Among the proposals are that the Ruhr be internationalized; that by the elimination of industrial districts and the general prohibition of industry, Germany be reduced to an agricultural state; and that production of power by Germany be stopped, and power be supplied to Germany from other countries and cut off in case of trouble.

International Aspects. International political control is hoped by many to offer a possible means of harnessing the industries of the Ruhr to peaceful reconstruction and of preventing their conversion to armament industries. Certainly the Ruhr was the principal source of manufactured goods and power on which German military might was founded. The history of international intervention in three German industrial districts and coal fields is instructive. The French occupation of the Ruhr in 1923 to enforce the payment of reparations met with many difficulties. The Saar, given to France for 15 years in payment for French coal mines damaged by the Germans, voted at the end of this period, in 1935, to return to Germany. Discontent over the international partition of Upper Silesia on the opposite boundary of Germany was one of the immediate causes of World War II.

The Ruhr is of international concern as a major originating and terminating point in international trade, most of which travels through other countries en route to or from the sea. Lorraine, part of Germany from 1871 to 1918, is a nearby source of iron ore, but after the political separation of the Ruhr and Lorraine in 1918 an increasing proportion came by sea from Scandinavia, Spain, and North Africa. Most of the grain and

iron ore moving inward to the Ruhr and of coal moving outward to the sea travels through the Netherlands on the Rhine River, although the machinery export moves principally by rail through the Belgian port of Antwerp. Because the mouth of the Rhine lies in the Netherlands, and German aspirations for control of the entire Rhine have never been realized, the Dortmund-Ems canal was constructed from the Ruhr to the North Sea by an all-German route; only a



FIG. 1. LOCATION OF THE RUHR DISTRICT

small proportion of Ruhr freight moves on it, however. Canals within the Ruhr district carry millions of tons of freight to the Rhine. Duisburg-Ruhrort at the junction of the Ruhr and the Rhine is the greatest inland port of Europe.

The German cartels, which have their chief home in the Ruhr, are of international concern, since they have become an instrument of national policy, particularly in the export of steel and chemicals. The cartels, which closely control production and sales, are federations of mammoth companies. Twelve such companies produce three-fourths of the

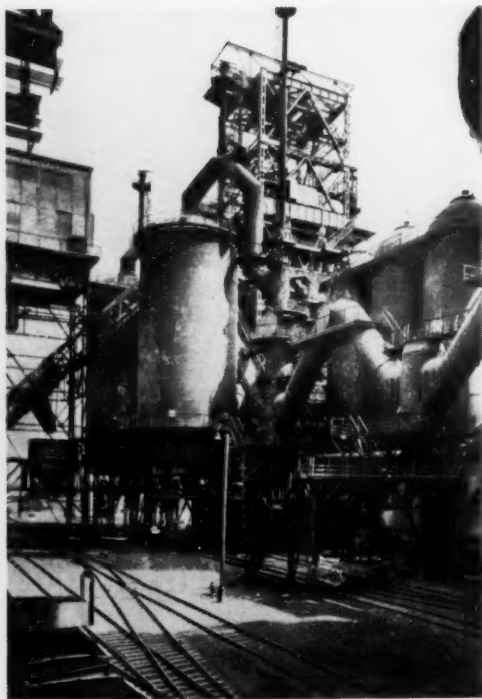


FIG. 2. A BLAST FURNACE
WITH HOT-BLAST STOVES, DUST CUT-OFF, GAS MAINS.

coal, and six of these are iron and steel companies with industrial empires including coal mines, coke ovens, integrated iron and steel works, and various processing plants. Nowhere in the world has vertical and horizontal integration of production been more highly developed.

The Industrial District. If Germany, including the Ruhr, is reduced to an agricultural economy, as some propose, the difficulties of reconstructing the over-run countries will be increased. In spite of intense aerial bombardment, the Ruhr probably still exceeds all other districts on the Continent in ability to replace the destroyed factories, machinery, and transportation equipment of Europe. In 1937 the pig iron production in the Ruhr (11 million tons) was about the same as that of the entire British Empire, and its steel production (nearly 14 million tons) was double that of France (Fig. 2). The dismantling of factories in the Ruhr would make the payment of reparations virtually impossible and would throw the

burden of rebuilding Europe almost entirely on the United States, which could scarcely hope for any appreciable repayment.

The Ruhr industrial district lies along the small Ruhr River, which flows westward into the Rhine, 40 miles downstream from Cologne and 40 miles upstream from the Netherlands boundary. The entire industrial area covers less than 3,000 square miles, a tenth the area of Ohio, yet with about the same population. In 1939 the Ruhr contained 6,800,000 people and 14 cities (Fig. 3) of more than 100,000 population, which are listed below:

Essen	666,743
Dortmund	542,261
Düsseldorf	541,410
Duisburg	434,646
Wuppertal	401,672
Gelsenkirchen	317,568
Bochum	305,485
Oberhausen	191,842
Krefeld-Uerdingen	170,968
Hagen	151,760
Solingen	140,466
Mülheim	137,540
München Gladbach	128,418
Remscheid	103,915

The Ruhr River marks the boundary between the contrasted northern and southern sections of the industrial district. In the north on the coal field between the Ruhr and Lippe Rivers are many coal mines and iron and steel furnaces. Seven cities of more than 100,000 population have contiguous boundaries in this section. The best-known and largest is the centrally placed city of Essen, from which Oberhausen, Mülheim, and Duisburg-Ruhrort form a solid urban area westward to the Rhine. Gelsenkirchen, Bochum, and Dortmund extend to the east. The iron and steel works of this northern section produced nearly three-fourths of the pig iron and steel of Germany before the war. Most of the production came from the thirteen huge integrated works shown in Figure 3; each of these is similar to the great American works at Gary, Indiana, in having co-ordinated blast furnaces, steel furnaces, and rolling mills (Figs. 4 and 5). They are located in the west in and near Duisburg-Ruhrort on the Rhine River, in the center in and near Essen and Bochum, in the east in Dortmund, and in Hagen to the south.

South of the Ruhr River off the coal field

are centers of light industry. Krefeld-Uerdingen and München Gladbach west of the Rhine and Wuppertal on the east are important centers of textile production. Solingen and Remscheid are the leading German producers of cutlery. Düsseldorf and Hagen are centers of metal-working.

Because of the vulnerable position of the Ruhr near the western boundary, the Nazis attempted to move the basic heavy industries to the safer interior. The attempt was

The Coal Field. One suggestion for the control of Germany is to supply electricity from other countries and to prohibit the reconstruction of old power stations or the building of new ones. The power of the coal mined in the Ruhr district in 1937, however, was equivalent to more than three times the total hydroelectric power generated in all Europe. The 127 million metric tons of coal mined in 1937 were equivalent to the power of 200 billion kilowatt hours of electricity

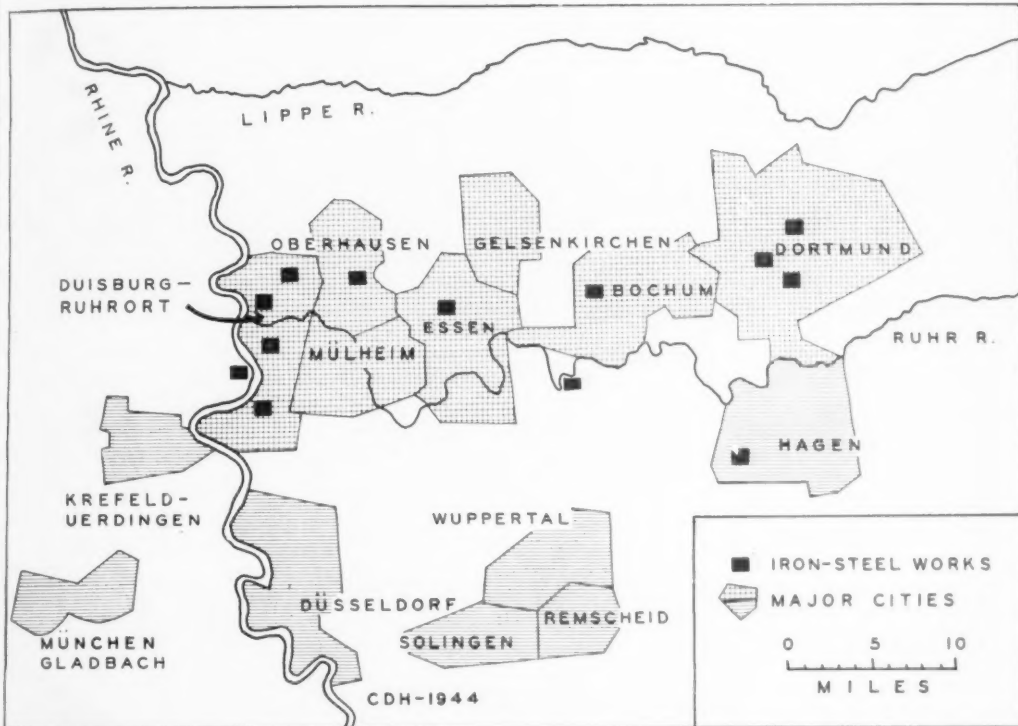


FIG. 3. THE MAJOR CITIES AND INTEGRATED IRON AND STEEL WORKS OF THE RUHR. THE COAL FIELD CITIES ARE SHOWN BY GRID PATTERNS; THE LIGHT INDUSTRY CITIES BY HORIZONTAL LINES.

largely unsuccessful, however, because of the economy of iron and steel production on the coal field. The coal and lignite of Saxony in the interior do not produce metallurgical coke. The Ruhr district contains the best coking coal in Germany. In 1937 it produced 32 million tons of coke, three-fourths that of Germany, and nearly half the total for Continental Europe (excluding the Soviet Union). All the coke ovens are located on the coal field in association with coal mines or blast furnaces.

but only 64 billion hours were generated from water power in Europe (excluding the Soviet Union). Furthermore, power generated from foreign coal could not easily replace that of the Ruhr, since the coal produced in this one district was approximately the same as the combined total for all countries which border on Germany: the Netherlands, Belgium, France, Switzerland, Austria, Czechoslovakia, Poland, Lithuania, and Denmark; the addition of Italy, Yugoslavia, and Hungary would not change the picture.

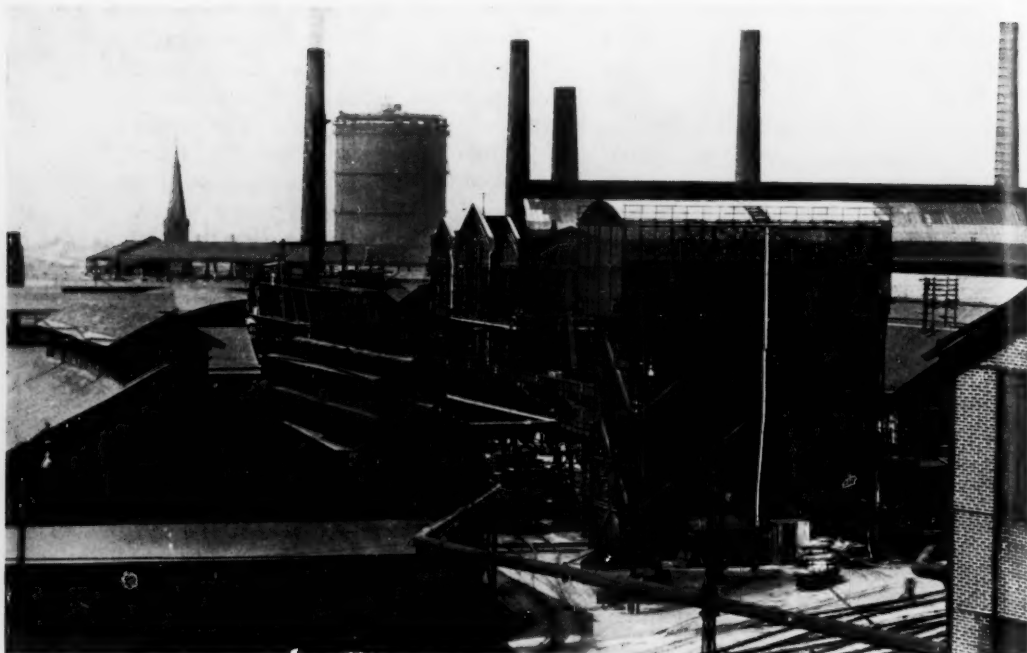


FIG. 4. PART OF THE KRUPP IRON AND STEEL WORKS IN ESSEN

THIS FAMOUS COMPANY MINES COAL AND PRODUCES COKE, PIG IRON, STEEL, AND MANY TYPES OF ARMAMENTS.

Instead of importing power, Germany usually exports 5-10 million tons of Ruhr coal to each of four nearby countries: the Netherlands, Belgium, France, and Italy.

In 1937 the 127 Ruhr coal mines had an

average annual production of one million tons each, many times the average production of individual American coal mines. The greatest concentration of producing mines is in a band 15 miles wide and 35 miles long.

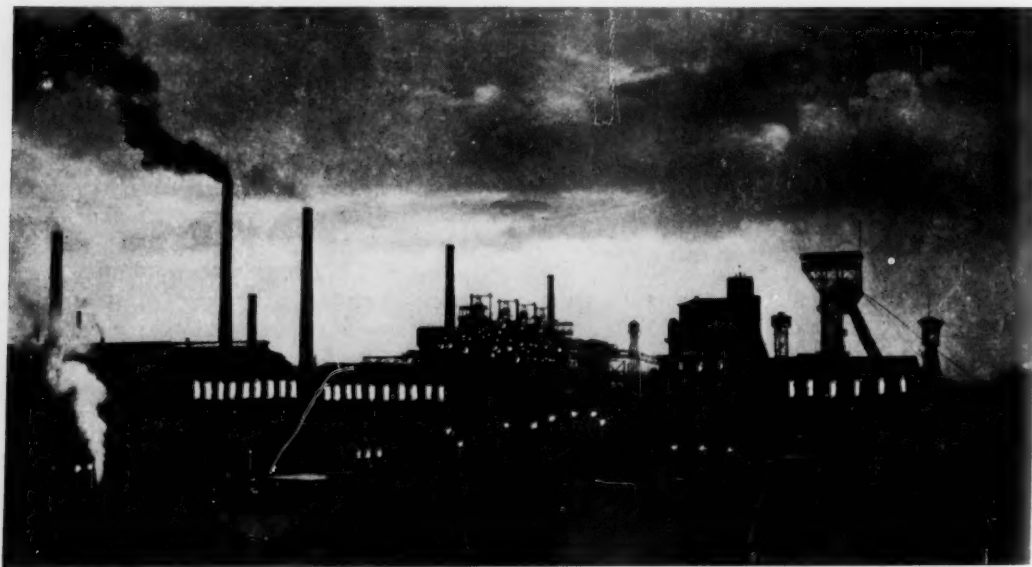


FIG. 5. THE BOCHUMER VEREIN IRON AND STEEL WORKS IN BOCHUM

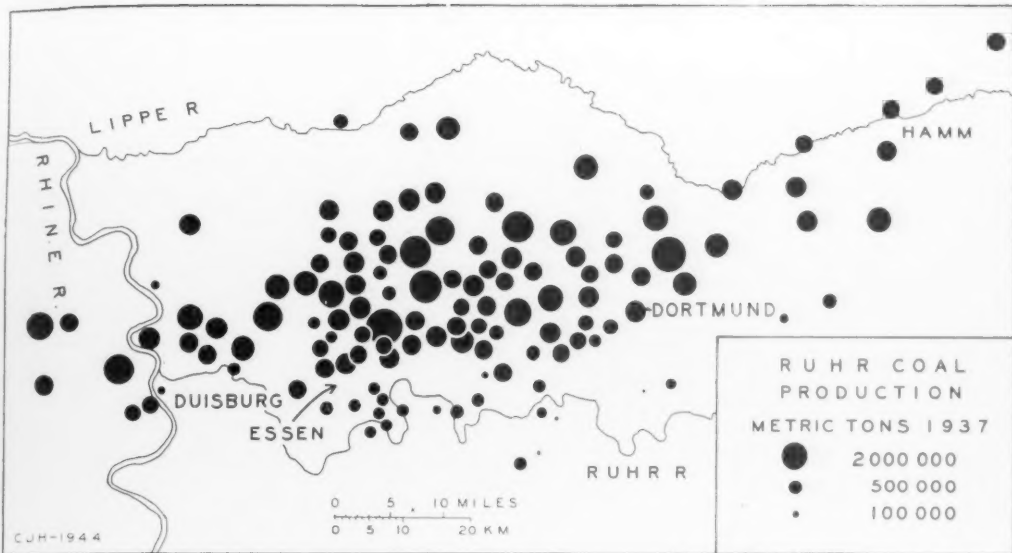


FIG. 6. COAL PRODUCTION BY MINES IN THE RUHR, 1937

which lies immediately north of the line from Essen to Dortmund, but the mining district extends beyond the Rhine on the west and to Hamm on the east (Fig. 6). The mines are several times as deep as typical American mines; on the average the coal is hoisted nearly 2,000 feet. Also in contrast with most American mines, which tap only a single thick coal seam, the Ruhr mines utilize many seams of moderate thickness (3-4 feet each).

By European standards the average annual coal output per worker in the Ruhr is high—double that of Belgium or France and 60 per cent greater than in Great Britain. This high output is the result of both the large production per shift and the high average number of days worked each year. The output per shift is greater than in Belgium or France because, in comparison, the Ruhr seams are thick, relatively uniform, and only slightly disturbed. The average number of days worked each year is high because production is stabilized by the powerful Rhenish-Westphalian Coal Syndicate and because many of the mines are owned by iron and steel companies, which have a steady year-around demand.

The coal strata outcrop along the Ruhr River to form an exposed coal field. South of the river the coal seams are missing but

to the north a hidden coal field extends at increasing depths for an unknown distance, perhaps connecting with recently discovered deposits in the Netherlands.

The total column of coal-bearing rocks is about 9,000 feet thick, but the complete column is seldom present. Within it are 57 seams of commercial thickness. From the lower strata to the upper there is a regular progression in the composition of the coal. The proportion of fixed carbon declines and of volatile matter increases; the coal in turn is semianthracite, semibituminous, coking bituminous, and high-volatile noncoking bituminous. Two-thirds of the total production is from the rich seams of coking bituminous coal.

The reserves of coal in the Ruhr are enormous. They account for 90 per cent of the deposits of Germany and may equal the combined total of all other coal fields of Continental Europe outside the Soviet Union. The concessions now being mined have enough proved commercial reserves to last for 250 years, and possible total physical reserves may be enough for 2,000 years at the present rate of consumption. Thus, barring unforeseen discoveries, the Ruhr district is likely to remain the most important European source of power.

WHAT FALLS FROM HEAVEN*

By DORRIT HOFFLEIT

ETYMOLOGICALLY 'meteor' signifies something pertaining to the atmosphere. Meteors (Fig. 1) are seen only when they become luminous in the upper atmosphere. They acquired their name, however, by virtue of the belief that they were purely atmospheric phenomena like lightning. According to the recommendations of the Society for Research on Meteorites, the word 'meteor' should apply only to the *luminous* phenomena accompanying the flight of a meteoroid (meteoric particle) through the atmosphere, meteorites being the tangible remains of those meteoroids that were originally large enough to have escaped complete demolition before arriving at the surface of the earth. Nevertheless, I prefer to use the word 'meteor' in a more general and loose way to cover every phase in the "lifetime" of a meteoric body except when special terminology is clarifying. Although meteoric material does not originate in the atmosphere, the terminology is again appropriate in the sense that recent studies of meteors, notably by Whipple at Harvard, have thrown new light on the structure of the upper atmosphere.

* From an address to the Rittenhouse Astronomical Society, Philadelphia, May 12, 1944. All illustrations of this article have been supplied through the courtesy of the Harvard College Observatory.

The Family Relationships of Meteors, Meteorites, and Comets. It was in 1798 that two students at Göttingen, Brandes and Benzenberg, began practical meteoric astronomy. They conducted simultaneous observations from two different locations according to the ideas of Chladni, who had already (1794) established the relations between meteorites and fireballs, between fireballs and meteors, and their possible connection with comets. Among over 400 meteors they had observed within a period of two months, twenty-two proved to be common to both observers. The average height of these twenty-two meteors, determined by simple triangulation methods, was 61 miles. From the durations of visibility it was apparent that their speeds were several miles a second (actually much underestimated). Hence, these students concluded, the meteors must have come from great distances—from beyond the distance of the moon. For a long time, however, this important discovery did not receive the attention it deserved. Then in 1833 the Leonids made a spectacular return—one of those showers the old woodcuts represent as looking more like a snow storm than any celestial display the average observing youth of today has ever witnessed. It was noticed that the meteors seemed to radiate from a



FIG. 1. TWO METEOR TRAILS

particular spot in the sky (Fig. 2). This was interpreted as signifying that the meteors move in parallel paths in space. The magnificence of the display in 1833 recalled the fact that a similar fine display had been observed in 1799, also in November. This coincidence led to a search of historical accounts which revealed that abundant meteors had been seen at this time of year at intervals of a little over 33 years. The conclusion reached was that Leonid meteors move in an orbit around the sun in a period of some 33 years. Their past reappearances were eventually traced back as far as A.D. 902. The consequent prediction of a brilliant shower for 1866 became beautifully verified. The outcome of the next prediction for 1899, however, was sadly disappointing, though scientifically revealing in that the importance of planetary perturbations became sternly evident.

Through such observations of the Leonids and other showers the extraterrestrial origin of meteors became established. Their association with comets (Fig. 3) was discovered soon after. In 1862 a faint commonplace comet was discovered. In 1866, when interest in meteors must have been unusually high, Schiaparelli noticed the similarity between the orbit of this comet and the path of the Perseids. The same year the orbit of the faint comet of 1866 was noticed by several astronomers (Schiaparelli, Peters, Oppolzer) to be the same as the orbit of the Leonids. Other coincidences were hunted and found, leaving no doubt as to the association of these two types of bodies.

For centuries, among people of practically all religions, meteorites (Fig. 4) seen to fall were sacredly guarded because the objects had fallen from "heaven." But the later scientific man had to find a logical explanation for these occurrences. Extraterrestrial origin seemed too farfetched. Meteorites had been *seen* to fall; but observations even by as renowned an astronomer as Lalande were treated with skepticism. By 1769 the question had become sufficiently important to be officially investigated. For this a commission was appointed by the French Academy of Science. We quote Nininger: "On this commission was no less a personage than the great Lavoisier, whose verdict, however, after



FIG. 2. THE ANDROMEDID RADIANT
THESE METEORS, APPEARING TO RADIATE FROM A VERY SMALL AREA IN THE SKY, ACTUALLY SHOOT THROUGH SPACE IN APPROXIMATELY PARALLEL PATHS.

an investigation, denied the phenomena, asserting that the stone examined was only a terrestrial rock which had become vitrified by lightning." But stones continued to fall from heaven till the truth would out. Finally in 1803 a single shower of stones amounting to from two to three thousand meteorites fell in France, at L'Aigle. The French Academy again appointed a commission, whose members this time became convinced of the now-accepted truth. Thus gradually the relation between meteorites and bright fireballs became established. The difference between these and the more common meteors is mostly a matter of size and velocity relative to the earth. The smaller masses and those that collide at the highest velocities with our atmosphere are consumed higher up. Only a small percentage of these cosmic missiles reaches the earth's surface. Thus through meteors we have a relation between meteorites and comets.

The history of the recognition of the character and habits of comets is much like that of meteors, though covering a much longer truly scientific period. Aristotle had considered comets as meteorological phenomena—"exhalations from the earth, inflamed in the upper air." From a consideration of observations of the comet of 1577 from various parts of Europe, Tycho Brahe discovered that



FIG. 3. COMET DANIEL 1907

METEORS HAVE BEEN FOUND TO TRAVEL ALONG THE ORBITS OF MANY BRIGHT COMETS LIKE THAT ABOVE.

it was farther away than the moon. Then Newton (1689) concluded: "For as comets were placed by astronomers above the moon, because they were found to have no diurnal parallax, so their annual parallax is a convincing proof of their descending into the region of the planets." Already in 1675 Hevelius had suggested that the orbits of comets might be parabolas, a theory that one of his pupils appears to have proved for the comet of 1681. But in most instances the parabolic nature of cometary orbits may be thought of primarily as a mathematical convenience, the difference between an elongated elliptical and a parabolic orbit being too small to be decided from the short arc that is observed near perihelion. Edmund Halley, commenting on the frequency of comet occurrences, became skeptical about

the convenient parabolic hypothesis. Inter-comparing the elements of the orbits of several comets, he ascertained that a comet observed in 1531, one seen by Kepler in 1607, and one he himself had seen in 1682 were all one and the same object. Examining further available records on comets, he found more such correspondences. "Hence," he wrote in 1715, "I think I may venture to foretell that it will return again in the year 1758. . . . Therefore astronomers have a large field wherein to exercise themselves for many ages, before they will be able to know the number of these many and Great Bodies revolving about the common center of the Sun. . . ." I believe we are still lacking this knowledge. We do know, however, that unless comets are being created in some manner as yet unknown, their number is probably diminishing. Certainly the sizes of the previously observed comets are diminishing; while newly discovered comets do not seem to compare in brilliance with the new ones of mere decades ago. Comet Cunningham, heralded as growing brighter after discovery, and Comet de Kock (1941), which was brighter than Comet Cunningham, are among the best examples of recent years. Surely they do not bear comparison with Halley's comet, Comet Morehouse (1908), Comet Daniel (1907), and many other "great" comets of the past.

In 1888 Theodor Bredikhine, then director of the Moscow Observatory, developed a theory of comets and meteors, showing how comets break up and how meteor streams are formed from them. By way of illustration he commented on the resemblances of the orbits of Comets 1843, 1880 I, and 1882 II, three comets whose periods range from 732 to 772 years. Bredikhine found that they were probably all parts of one large comet which had passed perihelion in the year 1110. Since Bredikhine's investigation several other comets have been found to belong to the same group.

Of all the known members of this group of comets, that of 1882 is the most interesting. Before it reached its closest approach to the sun, it had been a single large comet. After passing perihelion it had split into four comets. In a recent article S. V. Orlov of U.S.S.R. comments on the proba-

bility of meteor streams formed at the time of the disintegration of this comet. Searching the catalogues of meteor radiants, he finds that six observed meteor streams show association with the great comet of 1882.

At least two comets have actually been observed to divide into two. Biela's Comet (period 6.6 years) had been observed at four returns at which it showed no particularly remarkable features. Then on its return in 1846 it was seen first to become pear-shaped, then to divide into two parts. These twin comets travelled side by side for over three months before they passed from view. At their next expected return (1852) both reappeared, separated by about a million and a half miles. Since then, however, they have been lost. Another comet, Taylor's 1916 I, was similarly observed to divide into two.

Although Biela's twin comets have never since been seen, unusual meteor showers associated with them were observed in 1872 and 1885. In 1872 the numbers seen during one night by single observers amounted to over 10,000. In 1885 from 600 to 1,000 meteors a minute were seen. The fascinating history of the Bielid family of comets and meteors (also called the Andromedid meteors from the position of their radiant) is fully described by Olivier in *Meteors*, published in 1925.

Comets not only seem to disintegrate but may disappear from the solar system owing to the action of stellar perturbations upon them at large aphelion distances. E. Öpik, the Estonian meteor expert, has shown that when they are at large distances from the sun, where its gravitational pull is weakest, the slight pull exerted by other stars on a comet or meteor may be just great enough to move it out of its previous nearly parabolic elliptical path into one that is actually parabolic or even slightly hyperbolic. As these are not closed curves, future returns close to the sun are impossible.

How numerous are the meteors that we think of as the debris of comets? Watson's estimates indicate that the earth encounters about seven billion each day, down to the 10th magnitude. The total mass of meteoric material swept up daily by the earth is estimated at about one ton. As the earth encounters an extremely small fraction of the

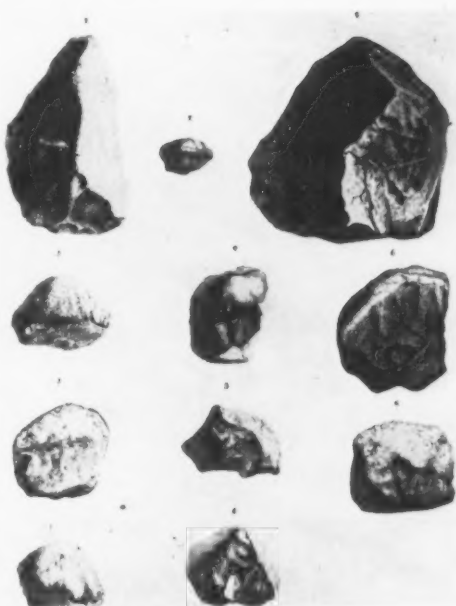


FIG. 4. SMALL METEORITES
THE GARDEN VARIETY OF "PEBBLES FROM HEAVEN."

whole, the problem of numbers of meteors is a fertile field for investigation. Strangely, perhaps, it is not confined to the solar system. Meteoric debris, not always associated with comet history, is found throughout the known universe. The material of Saturn's rings is probably much like meteorites. The same kind of material is probably responsible for much of the dark, obscuring matter in our Milky Way—regions such as the so-called Coalsack in the Southern Cross or the Horse-head nebula in Orion. Meteoric fragments also presumably constitute at least a part of the matter that produces the dark bands seen in spiral nebulae, especially the dark lanes of the spirals seen "edge on."

These lines of reasoning bring us to the converse possibility of the one discussed by Öpik. A stray meteoroid wandering between the stars may chance near enough to the sun to be "caught" by the sun's gravitational pull. Once within the bounds of the solar system further attractions by the major planets may even change its hyperbolic or parabolic orbit into a respectable elliptical one (Fig. 5). Thus new comets or meteors are possibly captured from interstellar space. A comparison of recent with former paths of the Leonids illustrates the capture theory.

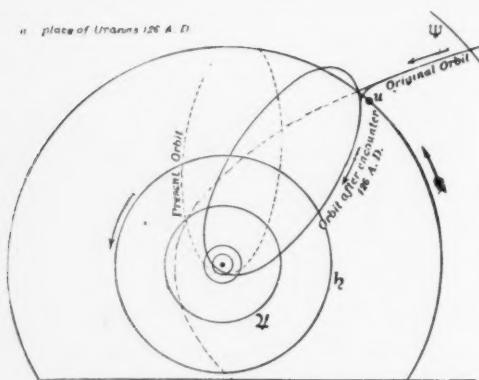


FIG. 5. THE LEONID ORBITS
THE PATHS OF THE LEONIDS BEFORE AND AFTER
THEIR SUPPOSED "CAPTURE" BY URANUS, A.D. 126,
ACCORDING TO CALCULATIONS BY LE VERRIER, 1867.

Have Comets Hit the Earth? It has been estimated by Russell, Dugan, and Stewart that a head-on collision between a comet and the earth might happen on the average about once every 80,000,000 years. The consensus of opinion seems to be that such an encounter would probably result only in a very brilliant display of meteors. The fall of meteorites would depend largely on the masses of the individual constituents of the head of the comet. In the event of a collision with a comet like Halley's, the diameter of the head being of the order of 500 miles, meteorites, if they fell, would cover a large area.

Two instances of meteoric falls may deserve consideration as comet-encounters, though the areas involved bear no comparison with the diameter of the nucleus of Halley's comet. One of these occurred in a more or less barren region of Arizona. There the famous Meteor Crater (Fig. 6), a mile across and 600 feet deep, is beautifully discernable from TWA's Grand Canyon Air Route to California. No huge lump of meteoric material has yet been recovered, although small meteorites are spread over an area five miles in diameter. If a large meteorite does exist (for which drillings give a fair indication), it is presumably buried well beneath the southern rim. When the meteorites fell, no one knows; estimates of the age of the crater based on geological considerations vary from 5,000 to 75,000 years.

The other possible case of a collision with a comet occurred in a Siberian forest on June

30, 1908 (Fig. 7). A brilliant fireball, observed at seven in the morning from a train about four hundred miles away, appeared half the apparent size of the full moon. On impact with the ground the meteorite or meteorites produced an "earthquake" of such intensity that the officials stopped the train, fearing a wreck. A column of fire was immediately seen to rise, and the noises from the explosion resembled, though exceeded, the din from artillery fire. The accompanying shock wave proved fully as disastrous as the fire, felling trees within a radius of thirty miles from the point of fall. Barometric records made in England (over 3,000 miles away) showed curious disturbances about five hours later that day. These were eventually attributed to the pressure waves in the atmosphere due to the meteor, for the time lag between the collision and these records is consistent with the velocity of sound.

That evening, sky-glow of great intensity were witnessed throughout Europe and the British Isles. It has been suggested that the sky-glow was produced by dust from the tail of a comet. This is an intriguing suggestion. But when one recalls that the density of matter in the tail of a comet is as low as that of the best laboratory vacuum, it is hard to conceive how so little matter could have influenced observed sky colors so greatly. The observed display was reminiscent of similar effects noticed after the great eruption of Krakatau in 1883.

It is indeed remarkable that so unusual a phenomenon as this Siberian fall—which caused considerable damage to the forest,



FIG. 6. METEOR CRATER, ARIZONA
THIS EXCAVATION MAY BE THE GRAVE OF A COMET.

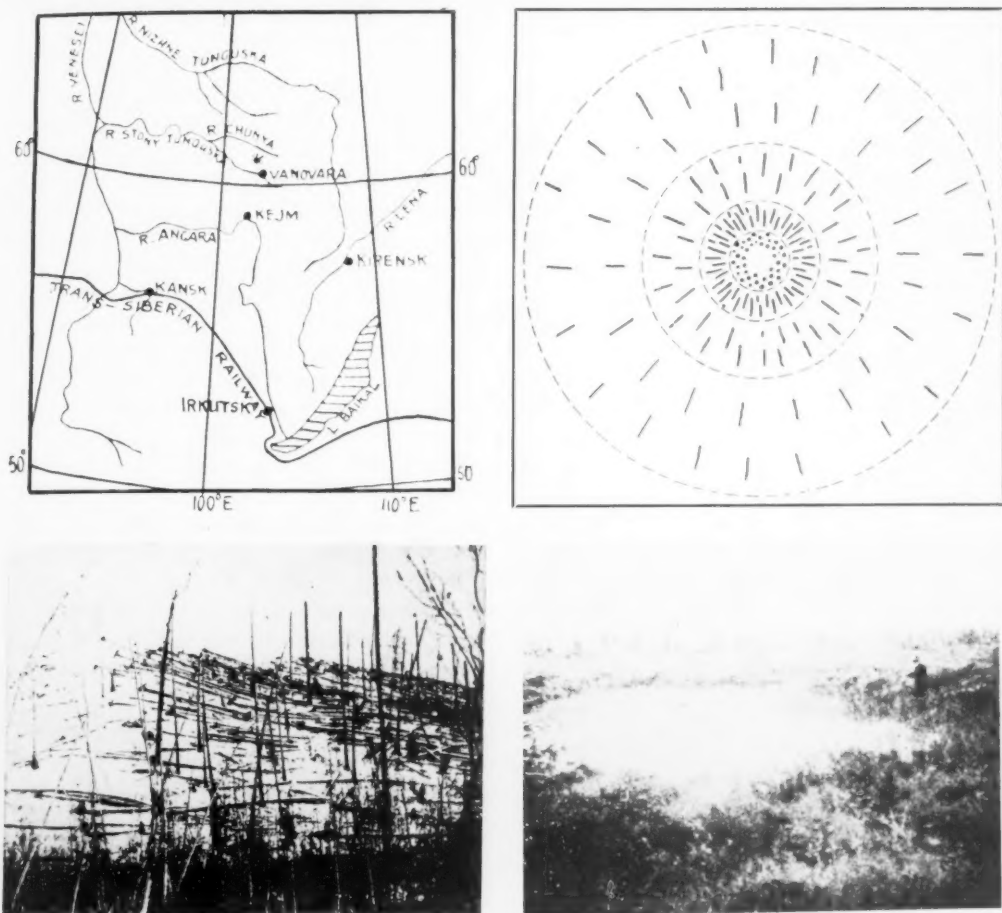


FIG. 7. THE GREAT SIBERIAN METEOR OR COMET FALL OF 1908

Upper left, THE ASTERISK NEAR VANOVARA MARKS THE SITE OF THE COLLISION, WHICH WAS FOUND IN 1927. *Upper right*, RELATIVE DESTRUCTION AND DIRECTIONS OF FALL OF TREES IN AREA 75 MILES IN DIAMETER. *Lower left*, WITHIN THE ABOVE AREA TREES WERE FELLED, BURNED, OR SCORCHED. PHOTOGRAPHED CIR. 1928. *Lower right*, A CRATER, WATER-FILLED, RESULTING FROM THE COLLISION. NO METEORITES HAVE BEEN FOUND.

wiped out a herd of fifteen hundred reindeer, injured people and property as far as fifty miles from the actual site of the fall (fortunately a sparsely populated region)—should have remained almost completely neglected for twenty years. True, in 1908 attempts were made to locate the point of the fall, but they were unsuccessful. Most searching parties at that time thought the meteorite fell near Kansk, several hundred miles from its actual location. In 1923 Professor L. A. Kulik, secretary of the meteor section of the Academy of Sciences, U.S.S.R., began collecting all available reports and information and in 1927 explored the Tunguska region. The exploration in swamp and woodland was a

very difficult undertaking, but Kulik succeeded in finding the area of fall, though no actual meteorites. Their craters, which he did discover, are water-filled and are among the smallest meteorite craters known. Probably the mass that struck the earth was not a single large piece but really a swarm of meteorites. From the energy of the seismic and barometric waves, and the huge destruction caused, the mass of the aggregate has been variously estimated. Noininger places the probable total weight at 40,000 tons.

Recently Noininger estimated the "bomb equivalent" of the 1890 fall of meteorites in Iowa. Of that fall about 300 pounds of meteorites were recovered. Assuming that these

bodies collided with the earth at a relative velocity of ten miles a second, he finds that if there had been no atmosphere the meteorites would have caused an explosion comparable to that of about 6,000 pounds of nitroglycerine. This is six times as destructive as some of the most effective modern bombs. Luckily our atmosphere has a great shielding effect. In the case of the Tunguska collision not only was the total mass of the meteoroids believed to be some 200,000 times greater but their velocity relative to the earth was estimated to be about four times faster. Since the sparsely inhabited regions of the earth cover most of its area, the probability of significant danger to humans from meteoric encounters is extremely slight.

Investigations in Progress. Before closing, let us look briefly at some of the work on meteoritics and comets that has been received from abroad during 1943-44 despite the war. Here is only a partial list of topics covered: the reality of observed hyperbolic velocities; meteor trains and their bearing on studies of the earth's upper atmosphere; the relationship of meteor streams to comets; exceptional comets; analyses of observational data both on visual and telescopic meteors; relations between aurorae and cometary phenomena; on the motions, structure, and disintegration of comets; physical theory of meteors; spectrophotometric studies of meteorites; a study of 125 cometary orbits; velocities of meteors; and physical characteristics of meteors based on 12,000 observations (obtained in New Zealand within a period of 15 years).

Perhaps the most intriguing of the long-standing problems in meteoritics concerns "hyperbolic meteors." From various lines of reasoning it seems certain that interstellar meteoric matter exists. Some of this matter, impinging on the solar system, should occasionally be observed striking into our own atmosphere. Yet whenever an astronomer has found evidence that such interstellar meteors have actually been observed, other astronomers have invariably found reason to question the validity of the observational evidence. "Interstellar" meteors move in hyperbolic orbits and it is from their veloci-

ties (though not exclusively) that hyperbolic orbits can be inferred. If a meteor at a certain distance from the sun is moving faster than a specific limiting speed (the parabolic limit) it will have sufficient momentum to escape from effective gravitational influence of the sun. Such meteors are moving in hyperbolic orbits. On numerous occasions apparent evidence has been found for hyperbolic velocities. Öpik, for one, devised ingenious apparatus for observing velocities, expressly in the expectation of finding concrete evidence for interstellar meteors. The observations required are delicate, and although his results indicated hyperbolic velocities, they are not generally accepted.

At Harvard it was hoped for a time that the meteor photography program inaugurated some years ago might yield a clearly hyperbolic case. At each of two stations separated by about thirty miles a patrol camera, covering a large area of the sky, is equipped with a rotating shutter. The shutter eclipses the lens about ten times a second. Should a bright meteor cross the field of the cameras, the meteor trails would be broken into small segments. Since duplicate photographs from the two stations yield the height of the meteor in the atmosphere, the lengths of the segments give the true velocity. No hyperbolic meteors have yet been photographed with this equipment. The Taurid meteors, formerly considered by Hoffmeister, the German authority on meteors, to be "interstellar" because of their stationary radiant point, have been numerous represented on these Harvard photographs (at least 14 Taurids). From an analysis of the trails, Whipple in 1940 brilliantly proved that Taurids are not interstellar catches at all. They are associated with Comet Encke!

Perhaps one reason why it has been possible for so much to have been accomplished during wartime is that the study of meteors generally requires less elaborate equipment than is necessary in other branches of astronomy. In fact a great deal can be done without the aid of anything more than a good pair of eyes, a common watch, pencil, paper, and a flashlight for recording observations—and wide-awake, serious enthusiasm!

THE IMPENDING SCARCITY OF SCIENTIFIC PERSONNEL*

By M. H. TRYTTEN

WHEN the full measure of American technological power was applied to the problem of producing war materials, the resulting flood of equipment not only astonished the world, including our own people, but has taken its place among the great phenomena of history. American know-how has achieved this triumph. And it is American know-how that is now threatened with partial atrophy. Technological know-how, from the level of the man who can fix a radio to the man who can design an electron microscope, is the result of training. It is this training that has ceased, particularly at the highest and most vital level where leadership is expected to arise. In the preparedness that was vital—technological preparedness—we were supreme. But this technological competence is now being permitted to decline.

Very few Americans have appreciated the full accomplishment of American science and engineering in this war. Most of our people become confused by the large numbers they hear. One hears of navies so large that the task forces cover hundreds of square miles, most of them produced since December 1941, when our fleet was thought broken. One hears of the prodigious American air fleet, thundering in thousands of great bombers over several theaters of war, transporting goods and men over every ocean, and darting into every hiding place of the enemy the world over. This has all been achieved within the memory span of school boys. One hears of guns, ammunition, tanks, bazookas, material of all kinds flowing in irresistible flood from factories that until three years ago never knew a product except for peace-time uses.

Assistant Secretary of War Patterson recently said:

That was our experience in World War I; it is also our experience today. Industries and universi-

* From an address delivered at the 58th Annual Convention of the Middle States Association of Colleges and Secondary Schools and Affiliated Societies.

ties have turned their laboratories and their test tubes inside out to give their country what it needed, whether they were summoned or not. Men and women who people those laboratories and wield the test tubes have given us more than we dared hope. Thousands of lives of our fighting men have been spared, most of the wounded restored to health. Our troops have been equipped with weapons, equaling or surpassing those of the enemy; final victory has been brought immeasurably closer, as a result of the efforts of our scientists and technicians.

The very magnitude of the flood of war goods from American factories should not blind us to that which is most significant about our war production. Mere quantity of material is not of main importance; it is the quality of American material that is of prime importance. A more maneuverable gun or one with a higher muzzle velocity, a stabilized tank turret, a system of gunfire control that multiplies the effect of each gun by improving its accuracy, a faster airplane, more powerful photography, more acute detectors of underwater sound, and a host of other examples would illustrate the point. These things multiply the effectiveness of each soldier, making him strategically the equivalent of many. They permit rapid, inexpensive victories, saving innumerable lives and reducing immeasurably the ultimate cost of the war in lives, in suffering, and in our resources for civilized living. In his report on the war in Africa, Field Marshal Kesselring spoke of the superlative performance of American tanks, easily outclassing the German tanks. Who can measure the value of this performance in lives saved and as a strategic factor in multiplying the strength of American arms?

Who can estimate the value, in strategic advantage or in lives saved, of the armament of the new B-29 superfortresses? The newspapers carry such tales of its powers as that which describes how one of these bombers beat off swarms of attacking enemy planes, shooting down 10 per cent of them without suffering damage. This is not an accident. The equipment on the B-29 is a culmination

of a technological growth in the United States that has its roots in the past and that has been intelligently nurtured since. Typical fruit of this growth is the highly special technological competence of the handful of men who designed the mechanism by which the guns of the B-29 are layed.

Reports of the Savo Island battle, which ended the Guadalcanal campaign, and of the recent battle of Surigao Strait have stressed the fact that these naval battles were fought at night with the use of "ultramodern" fire control equipment. How can one measure the strategic advantage of equipment which yields its users such complete certainty and accuracy in the dead of night that the enemy can be mortally wounded before he is rightly aware of the beginning of the battle? In both these battles the enemy seems to have lost every vessel. Our own losses were light. Yet the number of men who designed and developed this equipment is so small that they could easily have been guests at the battle on one of the destroyers taking part, and no extra accommodations would have been needed.

Hundreds of other cases could be cited; a host of other things have made our war effort most effective and least costly in lives. Much could be said of the brilliant work in discovering and producing new drugs and pharmaceuticals, in communications equipment, in photographic materials. Great work has been done in protective coatings and protective treatment for materials. All these cases are examples of the products of research at the highest level, turned over to the genius of American industry for production in quantity. Only this prodigious technological capacity could have made it possible for our relatively small armies to fight with maximum effectiveness on world separated fronts in relative comfort in contrast to former wars and with amazingly small casualty lists in comparison with the toll taken from our enemies.

The fact of the matter is that the products of the American laboratory and factory have been so potent that a whole new complexion has been put on the concept of preparedness. It must now be recognized that preparedness means first of all an adequate industrial establishment, backed by superior research

laboratories, ready to turn out the weapons and the equipment needed by war. In fact, war must indeed change its nature in some measure with each new scientific discovery.

The great achievements in this war of American technological know-how—which is after all nothing but applied science—would appear to any normal person to indicate that our scientific and technical skills are among our most prized possessions. It would seem to be a heritage of such precious value that the interests of the nation could be served only by its continued careful nurturing. If a small handful of men can perfect a device whose potency can tip the scales decisively in any naval battle, it should be the concern of the nation to find out how more men can be trained to similar competence. If a laboratory can contribute a remedy that will cut the disability due to sickness in a given theater of war by 50 per cent, one sees immediately that this laboratory has doubled the effectiveness of the forces in that theater. Why then should it not become of the utmost importance to place other men at work to extend this knowledge? Why should it not be of major importance to safeguard the future supply of men with this scientific training? The answers seem obvious.

It is now worth while to examine the record to see whether our policies have been intelligent. Have we in fact safeguarded our supply of men trained to carry on in the technological field? Have we in fact guarded our scientific and engineering pre-eminence? The answer is, unfortunately, "no." We have not only failed to safeguard our supply but we have actually followed policies whose effects must be to weaken our technology for years. Our policies have actually seemed to class this type of training with the most disposable elements among our institutions, to be cast overboard when the decks were cleared for action. Technological training has all but ceased in our colleges and universities. Selective Service has steadily drawn from the available supply of men already trained. And in the services many highly trained men are going to seed for want of continuous use of their training.

The training of men in the fields of science and engineering, as well as in other fields,

has largely stopped. What training is now carried on is of a sporadic and desultory character, depending on whether enough students are at hand for a course or whether a competent professor in the field is available. In one large university where a world-famous teacher in chemistry was wont to work with classes of one hundred graduate students in his specialty, there are now four, including two who are 4-F in the draft. We are committed to a policy of getting along with our present stock pile of trained personnel in the technical branches, even though that stock pile comprises a very perishable commodity.

This condition is due not so much to a faulty decision of policy-making individuals as to their failure to work out a policy. Competent people have not come together to work out a policy for the conservation of technological personnel to be implemented by law. There has been no lack of statements on the part of competent and informed leaders to show the effects of the present tenuous policy, but the creation of a new basic policy which would thereafter be determinative of subsequent action has not occurred. Conspicuously absent has been a clear-cut statement by highest authority that a highly technological type of warfare requires highly skilled specialists in civilian roles, that specialists of this type should be disposable for war purposes by a much more discriminating procedure than that of Selective Service.

As long as public opinion rates the man in uniform as performing a greater service than the civilian, and as long as the individual must take part by tacit consent in a request to defer his military service, the individual is not in a sound position. American feeling does not take kindly a man's implication that he is too valuable to fight, and no man should be asked to acquiesce to a request for his deferment as the only way the nation may retain his important services.

In the absence of a basic policy the inevitable result was that the local boards, who made the primary decisions in each individual case, were the source of determinative opinion. In general the Selective Service System and local boards have done a marvelous job. Their devotion and true democratic approach have been outstanding. But in dealing with highly specialized personnel,

requiring expert opinion, they were naturally not in possession of the background for correct consideration. The dead level of local board opinion and attitude was therefore determined largely by local considerations and has prevailed in determining the final effective national policy.

This national policy has therefore never been decided upon but has merely emerged as the statistical average of innumerable decisions with regard to individual registrants made by persons who could not possibly have been in possession of the necessary background to determine the demands of intricate modern technological processes.

The training of American scientists and engineers was accordingly doomed to disintegration from the first. Even in the early part of the war, when officially the students were permitted to remain in their courses, many were driven by social pressure to enter the services. The classrooms gradually emptied. When in the spring of 1944 the Selective Service system reduced to 10,000 the number of deferments permitted to students, it was discovered that far fewer than this number were left. Finally, in June of 1944, these deferments were cut off, and American universities and colleges settled down to await the peace before again going about the business of training scientists and engineers.

At the same time and for the same reasons the supply of active scientists and engineers has steadily dwindled. To be available for civilian work in the war effort, a registrant must be deferred. The great omission has been the failure of competent authority to attempt to determine the magnitude of the job to be done by industry and the laboratories and to allocate the available technically qualified personnel between these activities and the needs for the same kind of personnel by the services. Instead the disposal of each registrant has followed a familiar pattern. First he has been subject to a constant social pressure to don a uniform. If he has withstood this pressure, he has had to acquiesce in a request for deferment, repeated each six months and attendant with much red tape and formality. Endorsements by many individuals and agencies have been necessary semiannually,

involving in many cases hours of precious time on the part of valuable people. If in this long chain of events any link becomes temporarily fouled, the registrant is swept into the services. Thus the competence of industry and of scientific laboratories has been subject to a regular process of attrition. As a result, industry in many cases is capable now of only routine production of standardized items. The power and resiliency of the early days of the war when industry was staffed to meet new problems with brisk competence and confidence and to turn out amazingly effective new types of equipment in short order are no longer up to par.

Finally, the utilization by the services of specialized personnel within its ranks has left much to be desired. The general problem of classifying military personnel has been handled in this war in a manner much superior to that of the last war. But even the best of mass-handling techniques must break down when applied to small numbers of persons of highly specialized training. For this type of personnel, especially when severe shortages exist, a much more individualized type of procurement and assignment is necessary, and this should be done by those intimately familiar with the profession. Add to this the fact that even in a highly technological war the need for high grade scientific personnel is confined mostly to the research, development, and production phases of the war. The active services deal only with the finished product that more particularly needs maintenance personnel. It has been inevitable, therefore, that much of the scientific talent inducted into the services has been wasted. The Truman Committee of the Senate conducted a survey whose results have only been partly released, but these results indicate that about 90 per cent of the cases investigated by them showed partial or total waste of valuable training. It may be that this figure is unduly large, but no one who has dealt with high grade personnel can help knowing that many, many cases of poor utilization of such personnel are continually occurring.

WHAT evidence exists as to the effect of our lack of sound policy on our stock pile of trained manpower?

As an example of the kind of existing information, Figure 1 shows the number of doctoral degrees granted in American universities in the field of physics from 1913 to the present time. The first and most striking feature of this graph is the enormous rise in American competence in this field. This competence has, however, no more than kept pace with the demands of American industry for highly trained men. American business men found that the pace of development was such that only by the utilization of fundamental research could they expand as they deemed necessary. The fact that highly trained personnel in this and other fields was available to this extent was responsible for the enormous resourcefulness of American industry when confronted by the demands of war.

The rising trend shown on the graph is extrapolated on the assumption that it would not have changed had not the war interfered with training of men at this high level. One might also say that the trend measures the demand from industry and other activities for persons trained to this level. In reality this latter interpretation seems better to reflect actuality since every indication points to an unprecedented demand for persons of high competence in this field after the war.

The effect of the first World War is clearly indicated. It may be said in passing that the loss in national competence resulting from the granting of fewer degrees during the war years does not seem to have been counterbalanced by additional degrees granted later. The loss was not regained.

The downward trend in the curve following the outbreak of the present war is very sharp. The points on the curve are known through 1944. Only an estimate of the degrees likely to be granted in 1945 can be made, but some information is at hand on which to make a guess. Over the next two years it is known that the numbers may be very small. Recovery beyond that time is determined by a number of factors, all dependent on the length of the war. It is perfectly clear that no significant amount of graduate training is likely to be given before the end of hostilities in the Asiatic theater, unless present policies are altered. Those persons now doing scientific research for war

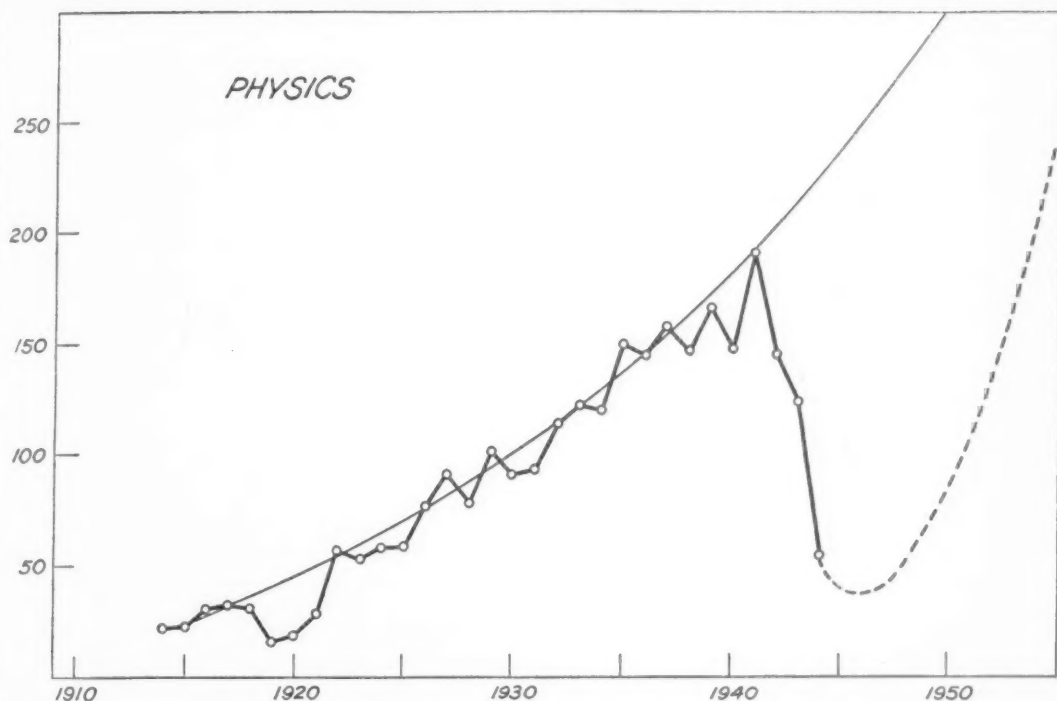


FIG. 1. NUMBER OF DOCTORAL DEGREES GRANTED IN PHYSICS SINCE 1913

purposes will therefore either keep on with their work or enter the services. The returned veterans who elect advanced training in the sciences are expected to be so few as

not greatly to affect the picture, because highly trained persons usually are assigned to important functions in the services whether utilizing former training or not.

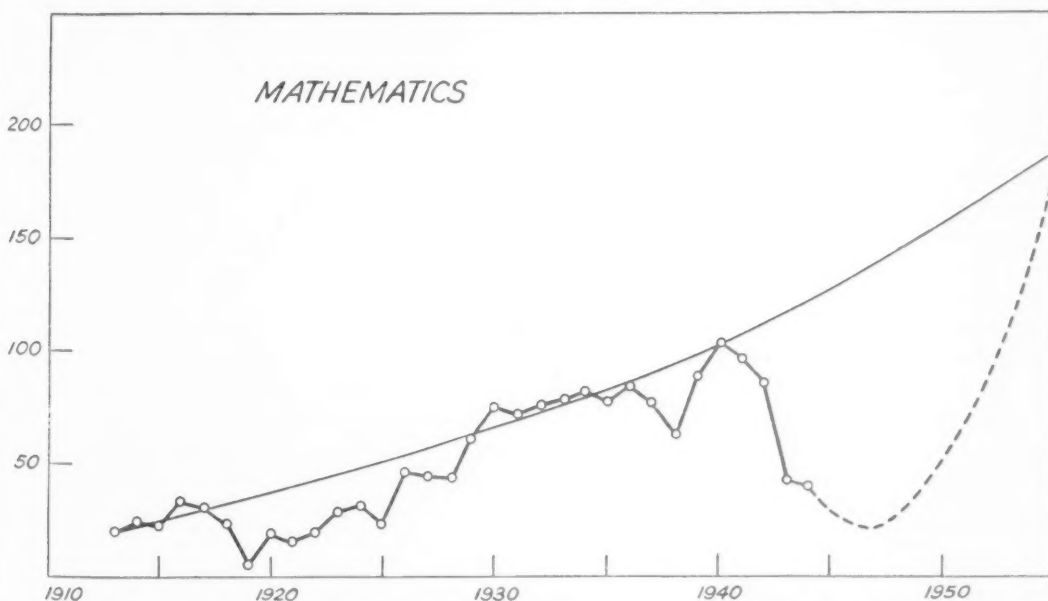


FIG. 2. NUMBER OF DOCTORAL DEGREES GRANTED IN MATHEMATICS SINCE 1913

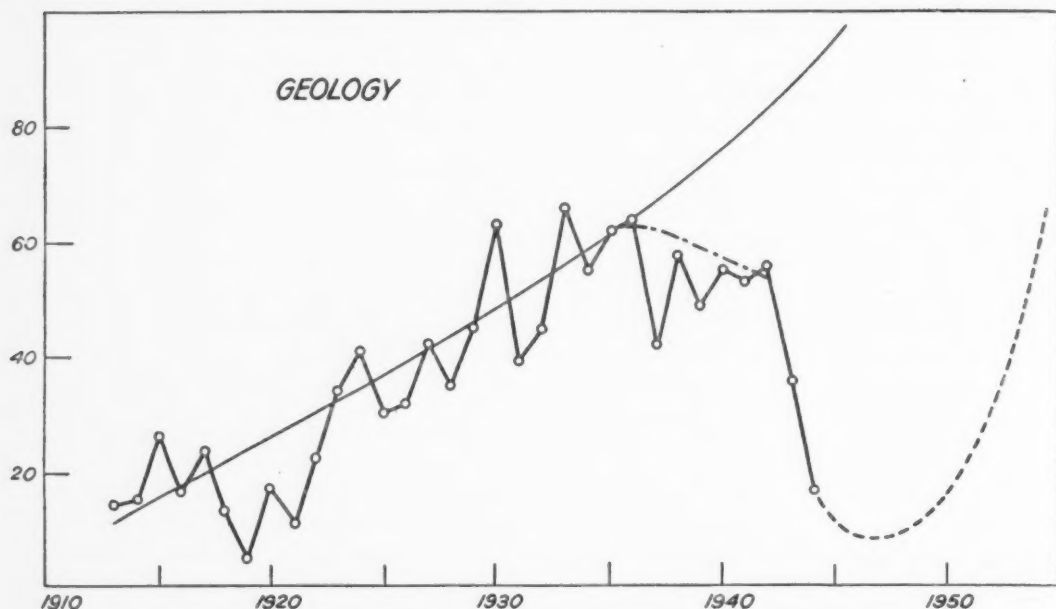


FIG. 3. NUMBER OF DOCTORAL DEGREES GRANTED IN GEOLOGY SINCE 1913

They are therefore in key positions and are not likely to be among the first demobilized. A study of the first cases of demobilized personnel bears this out.

Only after full-scale demobilization and restoration of normal university and college activity will significant numbers of persons begin to return to the graduate schools in

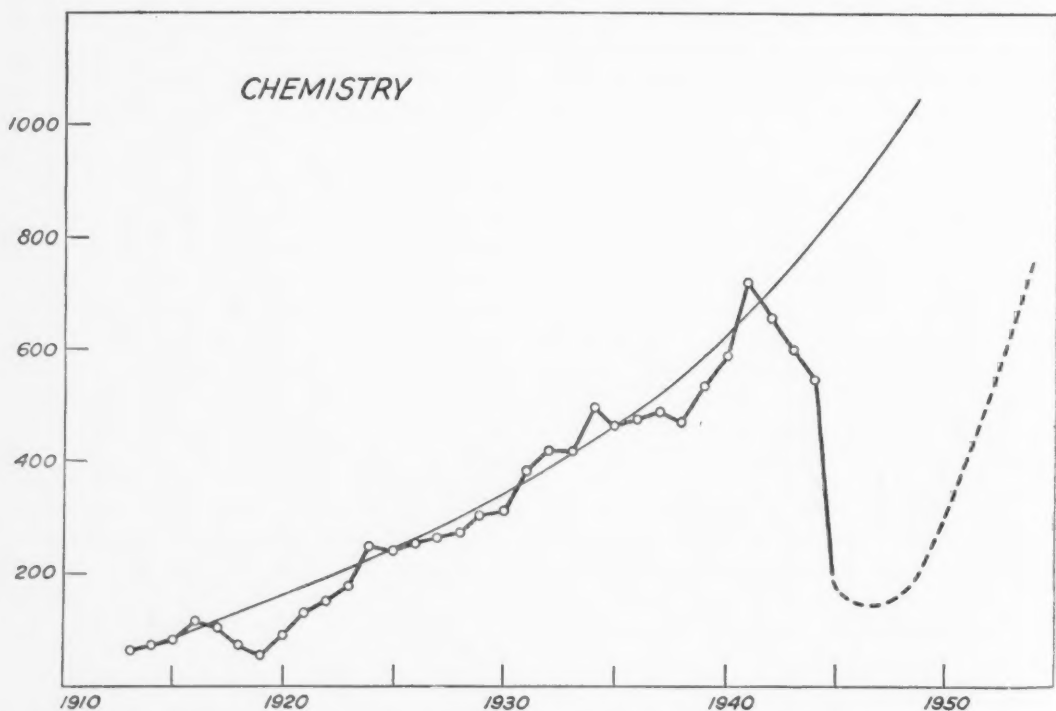


FIG. 4. NUMBER OF DOCTORAL DEGREES GRANTED IN CHEMISTRY SINCE 1913

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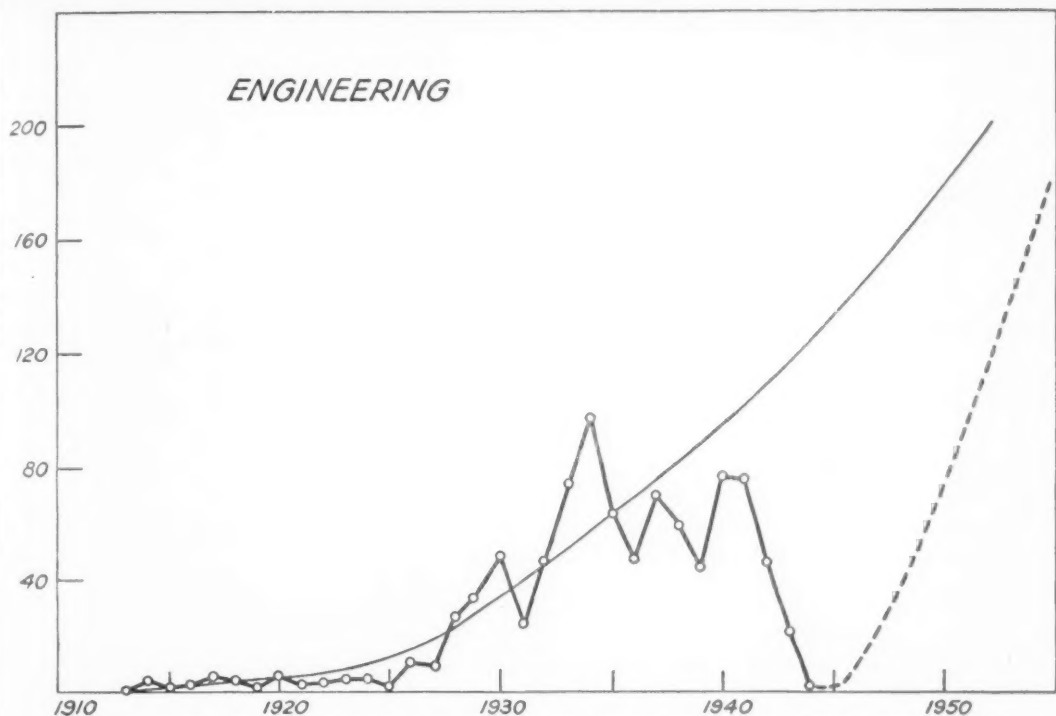


FIG. 5. NUMBER OF DOCTORAL DEGREES GRANTED IN ENGINEERING SINCE 1913

the sciences. It means that a full return to the trend shown in the curve must await the time when the first undisturbed classes can finish a normal four-year course in college and a normal career of graduate study. It is even questionable whether full recovery is possible. Therefore the suggested curve of recovery, promising a return to normal training by 1955, is probably conservative.

The graph of mathematics degrees (Fig. 2) agrees substantially with the graph for physics degrees in its shape and in the size of the deficit to be expected.

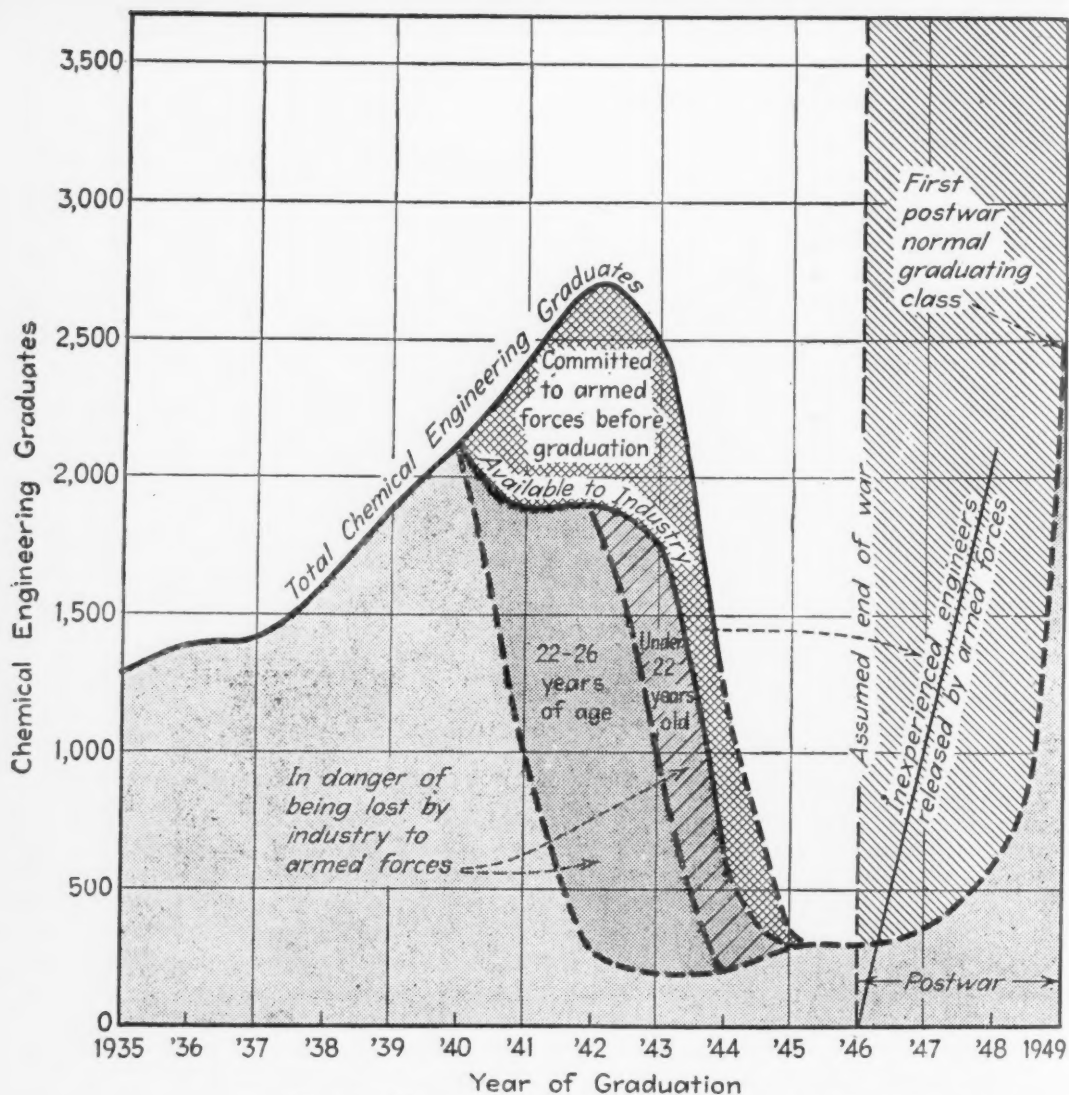
The case of geology (Fig. 3) is interesting in that it illustrates the effect of a sudden demand for the services of a scientific group. It has been pointed out by well-informed geologists that the break in the curve may represent the fact that attractive salaries for men with substantial training below the doctoral level were available in the thirties and that the resulting defection from the ranks of graduate students reduced the ultimate number who went on to receive the highest degree.

The case of chemistry (Fig. 4) is noteworthy in that the number of degrees shown

for 1942-1944 are much in excess of those for other sciences, even on a percentage basis. The present indication, as seen by leading chemists who have been interested in the personnel problem, is, however, that the number of doctoral degrees granted in chemistry in the year 1944-45 will be of the order of one-third of the number granted in 1943-44. Thus the future deficit in chemistry doctorates will assume about the same proportions as those in the other fields.

The data for engineering (Fig. 5)¹ are less clearly interpretable in view of the recency of the practice of granting doctorates in this field and in view of the small numbers of degrees granted since 1913. The trend is, however, the same. It should be pointed out that the rapid increase in complexity of engineering problems will no doubt create a corresponding demand for a corps of men trained to higher levels.

¹ The data for this and the foregoing graphs were obtained from the National Research Council and Edward A. Henry. The total number of doctoral degrees granted in each of the five subjects from 1913 to 1940 was as follows: physics, 2,257; mathematics, 1,374; geology, 1,010; chemistry, 7,859; and engineering, 781.



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FIG. 6. YEARLY SUPPLY AND DISTRIBUTION OF CHEMICAL ENGINEERING GRADUATES

Accurate information of a similar nature for the B.S. and M.S. levels is being assembled, but with greater difficulty. A graph (Fig. 6) of the situation in chemical engineering is shown as an illustration of the fact that corresponding deficits will probably exist at all levels. This should be borne in mind when contemplating rates of recovery. This curve represents the best judgment of the editors of *Chemical and Metallurgical Engineering*, in which publication it appeared (March 1944).

ONE can draw certain conclusions from these graphs, although admittedly tentative. The shape of things to come is determined by many factors, some of them predictable, some not. Within our own country the pace of technological development is profoundly influenced by economic factors as well as by educational and technical resources of men and facilities. But foreign influences as well are very important. We do not know what international relationships in trade and in politics will develop nor how profoundly

these may stimulate or retard our domestic progress. We do not know whether we are approaching a stagnating depression or a feverish period of frenzied activity. But in spite of basic uncertainties one can attempt to extrapolate the past into the immediate future in the light of discernible tendencies and trends and estimate in a rough way the extent of the problems confronting us. The data shown heretofore in this paper indicate that a heavy deficit of scientific personnel is to be expected at the leadership level. We shall now show evidence that there will be an unprecedented dependence on technological research and development in the immediate postwar years for military and civilian purposes. These are two divergent trends, the resolution of which may be a major post-war problem.

It is worth while to pause to point out that the nature of technological advance is like the expansion of a sphere, where a small change in radius produces a vastly greater increase in surface area. A new discovery may be the work of a relatively small number of scientists. But the full exploitation of this discovery may require many, many specialists of all kinds. It is not enough to understand the basic principle of the new discovery; there must be a full investigation of its every relationship, sometimes involving the work of diverse scientific skills, including not only mathematics and the physical sciences but perhaps also the biological sciences. The further reduction to manufacturing practice again involves ever larger numbers of specialists and ever more diverse types of training.

The first necessity for an expanding technology is therefore a steady flow of trained personnel. This flow must be at all levels, including the doctoral level, for modern industry is more and more dependent on the creative efforts of the research scientists. In fact it is becoming more and more evident that the future of the great American industrial establishment is to be peculiarly dependent on the fruitfulness of the fundamental science laboratory. Recognizing this, Dr. James B. Conant, President of Harvard University, said recently:

To this end we must see to it that as far as hu-

manly possible all the potential talent of the country in all these manifold activities is recognized at an early age and given adequate educational opportunity. Stepping out of my role as a chemist for a moment and speaking as an educator, this means a vastly increased support of public education—Federal funds administered through the States—and a much fairer distribution of educational opportunities at the college level. But I will remind you that in every section of the entire area where the word 'science' may properly be applied, the limiting factor is a human one. We shall have rapid or slow advance in this direction or in that depending on the number of really first-class men who are engaged in the work in question. If I have learned anything from my experience in Washington as Chairman of the National Defense Research Committee, it is that ten second-rate men are no substitute for one first-class man.

Even the regular pace of technological development, totally aside from any war-begotten development, would have required an ever-increasing flow of trained personnel at all levels, particularly at the higher levels. In addition, however, certain recent developments, including war-born developments, emphasize a dependence on our technological resources in the future.

One of these developments is the fear that because of their research facilities large businesses are likely to monopolize more and more the whole field of American industry. It is felt that small businesses cannot possibly compete without constant research and cannot afford to carry on research themselves. This often-spoken thought has led to a number of suggestions by certain Congressmen and by some Federal officials. Their suggestions generally involve either federally subsidized research for the benefit of small business or a method of disseminating latest information emanating from other sources. It will be noted that this presupposes an available supply of scientific manpower to carry out this function.

Large industry has shown every evidence of wishing to expand its research and development activities. This is due partly to the sharply increased competition expected after the war and partly to the tremendous accumulation of information growing out of war research and waiting to be exploited for the benefit of the public in the form of new devices. This backlog of unexploited technical experience will no doubt take years to develop completely for the uses of consum-

ers, since development will have to wait on consumer demand, but it seems quite safe to predict that a large volume of this type of research and development will be carried on at once after the war if competent scientific and technical men can be found to do the work. Again the demand on scientific manpower will be great.

As an example of what large industries expect, Harry L. Derby, President of American Cyanamid and Chemical Corporation, recently said:

I am confident that research in industry has not reached the ultimate in its scope and importance. According to figures compiled by the National Research Council, in 1920 about 300 industrial companies in this country employed 9,300 persons in research. By 1930 these numbers had grown to 1,625 establishments with personnel of 34,200. By 1940 the figures were 2,350 establishments and personnel of over 70,000. In other words, in 20 years there was more than a sevenfold growth in the number of people employed by American industry in research. Expenditures by industrial firms for this purpose have been estimated to be about \$300,000,000 a year. The future outlook, I believe, is for this trend to continue and for research to occupy a still larger place in the plans of industrial management and to exert still greater influence on our economic life.

Claude E. Williams, Director of Battelle Memorial Institute, emphasized what this would mean in the way of well-trained research men when he said recently:

In the intensified research program to follow the war, our most precious and critical resource will be well-trained research men. Our universities will do well to intensify and broaden their programs to include the training of men for research. Industry will do well to assist by the financial support of these programs. In this most essential activity, however, it is important that we do not lose sight of the product being sought—namely, trained research men.

The late president of the American Chemical Society, Thomas Midgley, Jr., squarely pointed out the basic weakness to be expected when he said shortly before he died:

It is doubtful if their number [meaning available research scientists] is much more than will be needed for replacement. Consequently, it is difficult to visualize any sizable expansion until our supply of scientifically trained personnel can be increased through the normal process of education. This will require at least a few years after the war ends; probably three or four.

Some of the more pressing demands will be those of the services for continued research in new weapons. Several of the large naval

research laboratories plan to continue with unabated effort after the war. The Army plans are not so well crystallized, but certain it is that never again will the American military establishment be permitted to fall so far behind in the matter of effective equipment. To this end a Federal military research organization under civilian direction is now being considered. It is likely that necessary arrangements will soon be completed. If this agency succeeds in securing the services of the necessary numbers of high grade research scientists, they will represent a significant part of the present supply. Again scientific manpower is needed. In commenting on research for war purposes, Assistant Secretary of War Patterson recently said:

While the arguments for the creation of the new agency are impressive, I do not believe that such an agency would fully solve our problem, for the problem is essentially one of men and women, not of organizations. We must have sincere and spontaneous interest in research pointed to national security, and this does not grow out of organizations and subsidies alone, however important these may be. Nor will it be possible in the government laboratories that will be continued in peace to carry through all the research in ordnance, aviation, radar, rockets, and new weapons, in the many specialized nutritional, physiological, and other fields which underlie the waging of modern total war. The research facilities and the scientific manpower prerequisite to those activities will simply not be available to the Government in sufficient degree. No acts of Congress or of the Executive Branch of our Federal Government can alone meet this deficiency. At almost every point of maintaining the technological strength of our armed forces—whatever mechanism we devise to achieve this end—we shall have to turn to the research laboratories and the research workers of industry and the universities to fulfill our needs. To some extent, as I mentioned at the outset, our task is made easier—paradoxically, I may say—because modern war is total war. In other words, much of the research carried on by industry and universities to meet the needs of peace will meet the needs of war if this tragedy should be thrust upon us again. In the field of chemicals, rubber, synthetic gas, electrical instruments, engineering products, medicines, light and heavy metals, and food products, research for peace is research for national security. Also in the case of certain end products of purely military use, the intermediary products may be suitable for civilian consumption.

As a further expression of the thinking of the War Department, Mr. Patterson said:

Research and development devoted to the weapons, tools, and techniques of war present us with a tough problem. Such research will not go on to the

extent required for our national security unless support, guidance, even control, emanate from central mechanisms. The War Department has grown increasingly aware of the need of research and development in connection with new weapons. In partial response to that need there was created within the War Department, more than a year ago, the New Developments Division. This division is charged with functions relating to the initiation and coordination of research and development and the expeditious application of new weapons, devices, and techniques. It has proved its usefulness and will, I hope, continue to do so in increasing measure. Its working relationship with the two scientific agencies to which we all owe so much—the National Research Council and the Office of Scientific Research and Development—has at all times been close and effective. I realize that this division marks only the beginning on the road to our goal. For in every one of its activities, after the war as now, the War Department must train its men, shape its plans and its actions to reflect the most recent advances of science. It must not lose sight of the fact that significant discoveries and inventions are usually the matured products of years of thought and experiment, with innumerable disappointments and failures along the way. There is no four-lane highway to scientific achievement; a bulldozer is needed every inch of the way.

Foreign governments are alive to the necessity of becoming self-sufficient scientifically and technically. There is now every evidence that America will be deluged with a flood of foreign students seeking the best training possible in American universities, colleges, and institutes of technology. The premonitory waves of that flood are already upon us. It is also possible that America will be urgently importuned to export some of its highest-grade personnel in the technical fields for the scientific and technical rehabilitation of the world. All of this will be a further drain on our stock pile of trained technologists.

But perhaps the most challenging thought is the fact that an expanding economy needs technologists to produce the expansion. We have been told that ours is a growing economy, that our geographic frontiers have given way to technological frontiers, and that discovery and invention will contrive new horizons for American industry. Thus, the constantly unfolding economy will provide jobs and prosperity for all.

As a concrete example of this thinking we may quote from a letter of November 20, 1944, from the President of the United States to Dr. Vannevar Bush, Director, Office of Scientific Research and Development. He asks in part:

What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge? The diffusion of such knowledge should help us stimulate new enterprises, provide jobs for our returning servicemen and other workers, and make possible great strides for the improvement of the national well-being.

If this constant technological expansion is necessary for continued prosperity, and if a steady flow of new technically trained persons is needed to carry on the technological expansion, the full danger of our policy of curtailed training becomes apparent. The present supply of technically trained persons will apparently be so busy keeping up the status quo that the necessary tempo of new development may not be possible.

These considerations should mean to science teachers a special awareness of the need for the highest devotion in the teaching of sound, solid work in the sciences at the beginning levels. We need an enhanced flow of capable men into the advanced levels of scientific and engineering instruction. It is in the interests of the nation as a whole that a flow of capable, sincere students in the sciences return as soon as possible to the regular training courses in the universities and the graduate schools.

At the very best, it seems to me that we face a period during which the demands of a war-stimulated technology will not be met by an adequate supply of scientists and engineers trained to the necessary level of competence. National security, both from the military and industrial point of view, will demand many more people than we have trained, largely because of our lack of sensible policy during the war. We can only be aware of this situation, put our shoulders again to the wheel, and carry on.

THE NATURE OF VIRUSES

By F. C. BAWDEN

THE scientific study of viruses dates from 1892, when their existence was demonstrated by a simple experiment made by the Russian botanist Ivanovski. He took juice from tobacco plants suffering from mosaic (a disease found wherever tobacco is grown) and passed it through a filter that stopped all microscopic bacteria. Nothing could be seen when the filtrate was examined under the microscope, and nothing grew in the filtrate when it was stored; yet healthy tobacco plants developed mosaic disease when rubbed with this seemingly sterile fluid.

As so often happens with momentous discoveries, no one was particularly impressed at the time. But four years later foot-and-mouth disease of cattle was found also to be caused by an invisible entity, and the potentialities of this new type of pathogen became apparent. The next forty years saw a rapid increase in the number of recognized virus diseases, which were found to include some of the most infectious and devastating kinds, and the viruses soon began to rank equal in their economic importance to fungi and bacteria.

During this time, however, the viruses themselves remained elusive entities, subjects of continual speculation but of unknown nature. They were generally assumed to be the smallest type of living organism, essentially similar to small bacteria, and the few opposers of this view had no facts to support their alternative suggestions. The study of viruses was therefore left mainly to pathologists; their work greatly increased the orbit of knowledge of many aspects of virus diseases, but their cultural and microscopic techniques were clearly ill-adapted for establishing the identity of agents whose two characteristic properties were invisibility and inability to multiply except in susceptible living organisms.

Within the past decade the study of viruses in both Britain and the United States has attracted workers from widely different fields, who have brought new techniques to

the subject and revolutionized our views. The first direct information about virus particles came from photographs of some animal viruses taken with a special microscope built at Britain's National Institute of Medical Research. The factor limiting the useful magnification of ordinary microscopes is the wave length of visible light; the new microscope had quartz lenses and worked with ultraviolet light, which has a shorter wave length than visible light and so permits the resolution of smaller particles. Photographs were made of several animal viruses, each of which was found to have approximately spherical particles of uniform size, while different viruses were found to have particles of different sizes. The use of ultraviolet extended the range of microscopy from particles with diameters of about 200 μ down to those with diameters of about 100 μ , but many viruses proved to be smaller than this and beyond the resolving power of this method.

Nothing in the ultraviolet photographs suggested that virus particles differed in any significant way from small bacteria, but the next advances, made with plant viruses, did. At the Rockefeller Institute, Princeton, N. J., the claim was made that tobacco mosaic virus had been obtained in the form of a crystalline protein. The methods used were those previously successful in the isolation of enzymes. The fact that tobacco plants suffering from mosaic disease contained a specific protein was soon confirmed by workers at Rothamsted Experimental Station and Cambridge University, England. They showed, however, that the protein was not a globulin as previously claimed, but rather a nucleoprotein, and that the needles formed when it was precipitated with acid and salt lacked the three-dimensional regularity of true crystals. Instead, they were liquid crystals of a type not previously discovered, though recognized as theoretically possible.

Solutions of the protein were highly infectious—0.000,1 microgram being enough to

cause infection when inoculated to a tobacco plant—and no such proteins could be found in healthy plants. It seemed likely that this protein, whose properties showed that its particles were larger than any protein previously studied, was the virus itself. Later work has supported this view, and the position of plant viruses as the smallest organisms is becoming increasingly insecure, while they move to a new home as the largest known proteins.

The study of purified tobacco mosaic virus proved of interest in fields normally regarded as far removed from pathology, for it possesses many unusual properties. The most striking include the ability of solutions to separate into two liquid layers, the upper being more opalescent though also more dilute than the lower, and the intense satinlike sheen they show when shaken. These properties are characteristic of rodlike particles. In the more concentrated lower layer these rods are spontaneously orientated, so that the whole fluid behaves like a crystal and is doubly refractive when viewed in polarized light. The rodlike particles in the more dilute upper layer are not spontaneously orientated, but their presence is easily detected by gently shaking the fluids in polarized light. For the rods are then orientated along the flow lines to form regions that become doubly refractive; solutions of tobacco mosaic virus show this phenomenon much more strongly than any other substance, and they may prove of value in hydrodynamics for studying flow movements.

There are well-established theories for calculating the sizes of dissolved particles from measurements on the physical properties of solutions. These theories had been used in previous attempts to assess the size of particles of tobacco mosaic virus. The discovery that the virus had rodlike particles, and that its solutions showed anomalous diffusion and viscosity, invalidated these estimates, and new methods had to be tried. The most interesting was the application of X-ray analysis, which was possible because of the crystallike structure of tobacco mosaic virus preparations. A special X-ray camera was designed at the Cavendish Laboratory, Cambridge, England, capable of measuring spac-

ings much larger than those previously used by the method.

X-ray measurements made on dried virus and on solutions of varying concentrations disclosed many interesting features. First, they revealed a previously unsuspected regularity in the structure of solutions by showing that the virus particles were always equidistant from one another and arranged so as to fill the available space as uniformly as possible. Secondly, they showed that the actual constituent units making up the virus were arranged with a perfect regularity. Thus, in effect, the virus was doubly crystalline, for not only can the particles arrange themselves regularly to give visible liquid crystals, but also the submicroscopic particles themselves resemble minute crystals. Thirdly, the measurements gave the width of the particles as 15 m μ ; they failed to give the length, but showed that it was at least ten times greater than the width.

Evidence from various sources led the workers in Britain to conclude that the greatly elongated particles characteristic of the purified virus preparations were formed by the end-to-end aggregation of smaller particles, and that the particles, as formed in the plant, were probably much shorter. This view was contested by other investigators, but it has now been confirmed by pictures taken with the newly developed electron microscope. This machine can be considered in basic principles as analogous to an ordinary microscope, but the light source and solid glass lenses are replaced by an electron source and magnetic field lenses, respectively. The wave length of an electron stream is many thousand times shorter than that of visible light and, in theory, should be capable of resolving particles of atomic dimensions. At the present stage of development of the lenses, however, spherical particles of diameter less than 20 m μ are resolved with difficulty. This is sufficient to cover the gap between measurements possible by X-ray analysis and the ultraviolet microscope and to resolve tobacco mosaic virus.

Unfortunately, material can be examined only in the form of thin, dried films, and in preparing specimens of biological subjects for examination there are clearly opportuni-

ties for changes to occur. Nevertheless, photographs taken at Rothamsted clearly show that tobacco mosaic virus occurs in particles of constant width but of widely different lengths and that the average length of the particles depends on the previous treatment of the preparation. How long the smallest particles are, still remains to be discovered, but they are clearly much shorter than the isolated particles that form liquid crystalline solutions.

It was soon established that tobacco mosaic virus is not unique in being an infectious protein. In rapid succession five other plant viruses, affecting tomato, cucumber, potato, and *Hyoscyamus*, were isolated. Some of these had properties very different from tobacco mosaic viruses, but all were found to be nucleoproteins with analytical compositions resembling that of tobacco mosaic virus; they all, also, had elongated particles and formed liquid crystals.

The next virus to be isolated at Rothamsted was that causing the bushy stunt disease of tomato, and this gave the first unequivocal virus crystals. It was again found to be a nucleoprotein, but it differed from those previously purified in containing three times as much nucleic acid. Its solutions showed no unusual optical properties or other anomalous physical behavior, for it has spherical particles. When precipitated with ammonium sulphate, it settled out of solution in the form of beautiful twelve-sided crystals (isotropic rhombic dodecahedra), sometimes large enough to see with the naked eye. X-ray measurements and studies of its physical properties gave the diameter of its particles as about 26 $m\mu$ and its weight equivalent

to a molecular weight of about 7,500,000. These figures have since been confirmed by electron microscopy.

From plants suffering from tobacco necrosis other specific nucleoproteins have recently been isolated. This disease seems to be caused by a number of viruses, all of which have spherical particles but which have different sizes and crystallize in various forms. These have been obtained in the form of thin lozenge-shaped plates, as hexagonal prisms, dodecahedra, bipyramids, and thin round laminae.

Thus, there is now almost incontrovertible evidence that many plant viruses are nucleoproteins, so that, chemically, they are much less complex than any recognized organisms. Whether this is true of all viruses, and especially of the larger ones with particles of diameters between 100 and 200 $m\mu$, must remain for future investigation to decide. These may prove to be more complex and to represent some intermediate form between proteins and bacteria. In spite of their chemical simplicity, however, even the small plant viruses have many features, such as the ability to multiply and mutate, usually regarded as characteristic of living organisms.

Living or nonliving is a controversy that has centered on viruses for many years, and it still continues. It has few immediate practical bearings but always arouses great interest. The answer of the virus worker will probably depend on the medium in which he studies his viruses, for in the test tube their properties are those of protein molecules, whereas in the infected plant or animal their behavior is that of living organisms.

ALCOHOL EDUCATION IN THE SCHOOLS*

By ANNE ROE

ALCOHOL education is required by law in all the elementary schools and in most of the high schools in the United States. It is included usually in elementary-school courses in health and hygiene, in high-school courses in health or biology, and occasionally in others. Some time ago I completed an analysis of alcohol education in elementary and high schools in the United States, the results of which were published in 1943 in the *Quarterly Journal of Studies on Alcohol*. I should like here to summarize some of my findings and conclusions, particularly as they apply to three pertinent questions: What does present-day education in the effects of alcohol consist of, how did it get that way, and what can we do about it?

Let me begin by giving a composite picture of what the textbooks most frequently include on the subject. There is often a preliminary section devoted to industrial uses of alcohol, usually more indicative of the attitude back of this education than pertinent to the problems of alcohol as a beverage. The most commonly included single aspect is a discussion of the general subjective effects of alcohol. The usual statement is that alcohol chiefly affects the higher mental processes of reasoning, judgment, and so on, and that this effect is accompanied by such physical manifestations as clumsiness and in-co-ordination. Remarks about the induced feelings of well-being, self-confidence, and relief from fatigue, all of which may occasionally be given as reasons why people drink, are usually accompanied by statements to the general effect that these are false feelings, that one is not really less tired or more confident but only feels so. I will not comment here on the logical difficulties to which such statements must inevitably lead.

There are a few texts which do not assume that any desire to be relieved, if only temporarily, from some of the pressures of life

is wholly reprehensible, and there are some which point out how to secure this end in other ways that do not have the repercussions of habitual recourse to alcohol. Many of the texts do distinguish in this part of the discussion between the effects of different amounts of alcohol, a distinction that from then on is usually lost sight of altogether. An amazing number of texts go into great detail about one or many of the studies of the effect of alcohol on such sensorimotor functions as typing and shooting. In no textbook have I seen such reports of analogous studies in other fields that the book covers, and I shall recur to this point later. (It may be remarked that a number of these studies are open to serious criticism on technical grounds.) The implicit, if not explicit, inference is always drawn that since the effects on sensorimotor performances are as stated, one should never drink. The drawing of conclusions not pertinent to the data is one of the most frequent errors in these books.

The next most common inclusions in the textbooks consist of remarks on the immediate physiological effects of alcohol and the eventual effects on bodily structures and functions. These discussions are almost without exception vitiated by lack of qualifications with regard to the amounts of alcohol concerned and by the persistence of incorrect conceptions of physiology, which lead to serious misrepresentations. For example, many texts contain such incorrect statements as that alcohol damages body cells, destroys tissue, or removes water from the cells. Very few texts make the basic point that the effects of alcohol depend upon the amount absorbed into the blood; a number contain flatly incorrect statements on this phase. Some matters—and their selection is in itself significant—are more often correctly stated than not, such as the fact that alcohol is absorbed directly into the blood stream and that this process takes place very rapidly. The discussions of oxidation are generally correct but perfunctory. It is unfortunate that this is completely divorced from the discussion of

* From an address presented on June 20, 1944, at the Evening Institute on the Treatment and Prevention of Alcoholism, sponsored by the Research Council on Problems of Alcohol, New York City.

nutrition, which is omitted altogether from many of the texts. Those that do discuss it often go into casuistical arguments to demonstrate that alcohol is not a food. It would be much better to show that it is an inappropriate food, for it cannot be too greatly emphasized that good discussions of the nutritional aspects of the problem would clarify the situation with regard to the effects of alcohol on the body generally, and particularly with regard to alcoholic diseases. The discussions of the effects on bodily structures and functions are not only frequently flatly erroneous but in many instances are so permeated with misconceptions of physiology that they are even difficult to criticize. The effects of alcohol on disease resistance are more or less correctly reported except that it is rarely made clear that, so far as known, small amounts of alcohol do not impair disease resistance in general. In part as a consequence of the failure to discuss adequately the nutritional aspects, alcohol as a cause of disease, either physical or mental, is rarely correctly presented.

It is generally correctly explained that alcohol is a depressant rather than a stimulant, but no attempt is made to explain the effects that give the appearance of stimulation. The habit-forming properties of alcohol are almost invariably likened either directly or by implication to those of narcotics, such as morphine or cocaine. This comparison is physiologically incorrect and pedagogically unnecessary. At our present state of knowledge, habituation to alcohol can be explained only as a psychological process. Most texts in health make a point of discussing the psychology of habit formation in general; surely it should be easy to extend this to alcohol. References to other physical and psychological aspects of the problem are scattered, but of about the same quality as those that have been discussed.

The social aspects of the alcohol problem receive relatively little attention, with one exception. That is the relation between alcohol and traffic accidents. The majority of the texts that discuss this do a very good job of explaining why drinking may lead to increased traffic accidents. More emphasis might be placed, however, on the revocation

of licenses for drunken driving, and certainly it would be well to include material on chemical tests for drunkenness and their value and use. The statements regarding alcohol and industry are generally acceptable, as are also those about the deleterious effect of excessive drinking on home life. Statements regarding alcohol and crime are not always too well chosen.

It was startling to find, as a rule, no discussion of public responsibilities in the matter of education or control measures or care of alcoholics. An even more startling omission is the failure of all but two texts to mention treatment for alcoholism. In most texts it is clearly implied that once an alcoholic, always an alcoholic. This is not only socially reprehensible but, I think, quite significant with regard to the motives back of this teaching.

I have not attempted in this brief survey to cover more than the high lights of the actual content of present-day alcohol education. It is clear, I think, that our educational materials are worse than inadequate. The question immediately arises as to how this has happened. Are misinformation and misconceptions on this scale characteristic of instruction in all fields of study, or is there a special problem in this particular field? In an effort to answer this fairly I submitted some of the texts in biology and general science to a leading scientist and asked his opinion of the material therein. He did not make an extensive analysis but stated that there were a great number of errors, most of them minor ones, but not a few major ones. But the situation was by no means so bad as that in the alcohol material, although it was by no means so good as it might be. The reasons for the inaccuracies in our science textbooks may be sought in the way in which these texts are produced. They are usually written by elementary- and secondary-school teachers who are not, themselves, scientists. The impression is clear that their sources are largely previously published general textbooks. General textbooks, even on the college level, always lag behind current knowledge, and it is obvious that the lag must become even greater in other textbooks and that with this system the perpetuation of errors from one genera-

tion of textbooks to another is inevitable. (It is, of course, true that even research scientists frequently perpetuate errors by failing to examine original sources critically.) Furthermore, it is often extremely difficult to avoid misstatement when very complicated conceptions must be simplified for pedagogical purposes, but this factor I have taken into account. In short, all our textbooks in science could do with careful critical examination; in my opinion textbook writers, publishers, and research scientists are all at fault in the matter, and perhaps the research scientists, who rarely seem to feel that it is an essential part of their function to make their findings easily available to society, are most at fault.

But to revert to our specific problem. It appears that the situation in the field of alcohol education is even more unsatisfactory than it is in education in general. The reasons for this are clear. If one knew nothing of the history of the movements that brought this teaching about, or had heard nothing of the laws that specifically single out this subject for inclusion in all school curricula, one would still sense that some emotional factors were at work in this field. The evidence is in the material offered for instruction. The inclusion in a textbook in biology, for example, of a discussion of the merits of alcohol as a solvent for varnish is evidently motivated by a wish to demonstrate openmindedness to the extent of willingness to admit that alcohol has some use in the world. Why go into great detail about the findings in various sensorimotor researches in this field and in no other, even where these would be equally pertinent, if not to give the illusion of scientific accuracy? Why omit all discussions of the possibility of treatment and cure of alcoholism? Why the constant omission of differences in effect with differences in amount ingested? And finally, why are all the errors in the same direction? This cannot be accidental, though I do not mean to imply that there has been deliberate intent to mislead. I mean only that emotional factors are involved. It has happened in this instance because by far the largest part of the source material used by the writers of these textbooks has come not from scientific sources but, directly or indirectly, from lay groups

with a specific interest. This has been so because, in the first place, the scientific material has been so disorganized and so controversial that wading through it and critically evaluating it would be an impossible task for the ordinary textbook writer; and, in the second place, because the publishers have generally seen to it that the material included in their textbooks met with the approval of the interested lay organizations. Obviously the easiest thing to do has been to use material supplied by these organizations. That the publishers have relied so heavily upon these groups is simple realism on their part—it was these groups that brought about the legislation requiring alcohol education, and they alone manifest any particular concern over what is being taught. Further, the present claim of these organizations, which I am sure they sincerely believe, is that their material is “scientific, unemotional and pedagogical,” and this claim is widely accepted as true, partly because it is constantly reiterated and partly because of the discontinuance of the diseased-liver picture, horror-story type of material they put out earlier. Analysis of the material, even in this brief sketch, shows that the present teaching does not live up to the claim of being scientific and unemotional, nor can it be reconciled with sound pedagogical principles. The teaching, as it is today, reflects anxiety that objective, scientific presentation of the subject might frustrate the aims tacitly incorporated in the statutes.

What shall we do about it? Let us, in the first place, try to get a sense of proportion. The problem of alcohol has two chief aspects, social and personal. In educational work attention has been almost exclusively directed toward the latter aspect, and on a concealed moralistic basis. I believe that drinking is, in a sense, a moral issue, or rather that it is one aspect of a moral issue. But it is only one aspect, and very often a minor one, and nothing will ever be gained by treating it in itself as an isolated and specific moral problem. The issue is a much larger one. The primary responsibility placed upon every individual in our democratic society—as it is, I think, the ultimate moral issue for everyone—is the harmonious development of

his own personality, the reconciliation of his own internal conflicting drives, and his integration into society. Alcohol may play any one of a number of roles in this problem; to focus our concern upon the specific act of drinking reveals only our own flight from the immensity of the real problem. We need a new orientation and a much greater understanding before any effective approach can be made from this angle.

But in the meantime we have definite social problems of what to do about the alcohol addict and the chronic alcoholic. These are public-health problems; they exist on such a large scale that no private institutions or organizations can begin to cope with them. We have practically no public provisions for the treatment of alcoholics. We shall not get such public provisions until people are educated to the necessity for them and to the possibilities they offer. The high-school stu-

dents of today are the voters and legislators of tomorrow. Large public funds are needed to solve these problems, and when the public finds itself expending large sums yearly upon the treatment of alcohol addiction, it would not be surprising to find considerably more interest manifested in the cause of this addiction.

Let me suggest, then, that we set up a dual aim in our education in this field. Let us investigate, and help our students investigate, what immediate steps society can take to care for and treat the alcoholics already in our midst. Let us also revise our education with regard to the more personal aspects of alcohol by clearing away all the deadwood of inaccurate statements and misconceptions and by trying to see the problems of alcohol addiction as aspects of the mental and emotional hygiene of the individual and of the society in which he lives.

AJAX

The long historic path of scientific thought

*Is strewn with wrecked hypotheses, brought low
By inner flaws; for truth survives the alien blow
And lives to justify what man so dearly bought.*

*Of slower growth the vital realm of common sense,
The extra factual judge of value, hope and faith,
Encumbered by taboo, by self and thoughts of death
And all the fancied world beyond experience.*

*Demanding evidence for all the therapeutic claims
Of doctor, witch or saint, of visions, drugs and glands,
And honesty of heart for which no guile atones,
The choice of worth from welter of conflicting aims
A Trojan battle proves. Our valiant Ajax stands
Foursquare to foes of truth as leader or alone.*

—J. G. SINCLAIR, November 1944.

THOMAS JEFFERSON AND AGRICULTURAL CHEMISTRY*

By C. A. BROWNE

THE life of Thomas Jefferson, between the years 1743 and 1826, coincided with one of the most fruitful periods of man's political and scientific development. Few eminent men have witnessed the birth of so many branches of modern science as he. Lavoisier, who established the principles of modern chemistry, and Haüy, who laid the foundations of modern crystallography and mineralogy, were born in the same year as Jefferson. Jussieu, whose work formed the basis of the modern system of classifying plants, was born only five years later than Jefferson. But Jefferson, although pre-eminently the leader in the revolution against political tyranny, was most conservative in his attitude toward the revolutions that were taking place about him in the world of science. He looked with a certain amount of misgiving upon the much-needed reforms that Lavoisier, Haüy, and Jussieu were accomplishing in their respective fields.

In addition to the three men just named, a few other prominent scientists, who were born in the same decade as Jefferson, are deserving of mention. The great agricultural writer Arthur Young, three of whose works were in Jefferson's library, was born in 1741. The celebrated botanical explorer André Michaux, with whom Jefferson was personally acquainted and whose *Flora Boreali-Americana* was in his library, was born in 1746. Jefferson's friend and fellow signer of the Declaration of Independence Dr. Benjamin Rush, distinguished physician and first professor of chemistry in the Philadelphia Medical College, was born in 1745. The Swiss scientists Horace Benedict de Saussure, the Alpine explorer, and Jean Senebier, the plant physiologist, both of whom Jefferson thought at one time of inviting to America, were born, respectively, in 1740 and 1742. De Saussure was termed by

Jefferson one of the best philosophers of his time. The English physician Dr. Edward Jenner, whose discovery of vaccination caused Jefferson to write to him "mankind can never forget that you have lived," was born in 1749. These are only a few of the scientific celebrities who were born in the same decade as Jefferson. If we should name all the eminent European and American men of science who were contemporaries of Jefferson at one period or another, the number would exceed one hundred.

All students of Jefferson's life are impressed by the fact that in the midst of the turbulent political events that so long engaged his chief attention he could not only keep well informed in chemistry, botany, zoology, geology, geography, meteorology, cartography, agriculture, and other sciences, but could become so well-grounded in some of these fields of knowledge that he helped promote their advancement by original contributions of his own. The career of only one other American statesman presents so many parallels of diverse activity—that of John Winthrop, the younger, first Governor of the Connecticut Colony, whose career, although a century and a half earlier, presents a surprisingly large number of resemblances with that of Jefferson. Both men were statesmen and governors; both were farmers, large land holders, and interested in the improvement of agriculture; both were practically acquainted with many branches of science; both were members of scientific societies, Winthrop of the early Royal Society to which he contributed a paper on "The Culture and Use of Maize," and Jefferson of the American Philosophical Society of which he was the third president and in which he initiated a research on the control of the Hessian fly; both complained that affairs of state interfered with the pursuit of science, which was their chief enjoyment; both had a wide acquaintance among the eminent scientists of their day with whom

* Paper prepared in connection with the program of the National Agricultural Jefferson Bicentenary Committee.

they conducted an extensive correspondence, Winthrop with such celebrities as Boyle, Digby, Oldenburg, and Moray, and Jefferson with such notables as Franklin, Rittenhouse, Priestley, Wistar, Barton, and Humboldt; both collected the largest private libraries of scientific books of their time; both built up private museums of natural curiosities, some of which, as Winthrop's specimen of columbite and Jefferson's bones of the Megalonyx, have played a significant role in the history of American science; both were philanthropists, interested in the promotion of education and the public welfare; both left extensive collections of private letters that are most valuable sources of information to students of the history of American science. Still other parallels might be added to the list.

Many conceptions of ancient and medieval agricultural science survived in Winthrop's time, and some of them persisted down to, and even beyond, the period of Jefferson. One of these traditional beliefs was that all products of agriculture were composed of the four ancient elements—earth, water, air, and fire. Abnormalities in the proper balance of these components were supposed to explain the sterility of soils and the diseases of plants and animals. Winthrop's friend Robert Boyle expressed his doubts about this conception of four elements in his *Sceptical Chymist*, but the idea was too deeply rooted to be easily overthrown. It continued to be expressed by many authors of books on husbandry in the eighteenth century as, for example, by that voluminous agricultural writer Richard Bradley in his *Ten Practical Discourses Concerning Earth and Water, Fire and Air, as They Relate to the Growth of Plants*, published in 1727. It was one of the books in Jefferson's library at Monticello; its influence and that of other similar works upon Jefferson is indicated by a passage in his *Notes on Virginia*, written in 1782, where he states: "It is by the assistance of heat and moisture that vegetables are elaborated from the elements of earth, air, water, and fire." Allusions to an elemental water, air, and fire did not completely disappear from agricultural literature until after Jefferson's death, so it is not surprising that a few slight

implications of these old doctrines should appear in his writings.

Agricultural chemical reports to the Royal Society, similar to those made by Winthrop for New England, were made later for the Colony of Virginia by John Clayton, an English rector well trained in chemistry, who transmitted to the Society an account of the observations that he made during a residence in Virginia between 1684 and 1686. Clayton lived on a tobacco plantation, and the parts of his reports relating to the waters, soils, and fertilizer resources of early Virginia and the effect of different soils on the quality of tobacco give a graphic picture of the theories and practices of agricultural chemistry that prevailed at that time.

Chemistry, at the time of Jefferson's birth, was just emerging from a long barren period of medieval superstition and scholastic speculation. Floods of books were still appearing on alchemy, astrology, and other pseudo-sciences with their references to the operations of demons, salamanders, planetary emanations, and other occult influences. It was the famous Dutch physician and chemist Hermann Boerhaave (1668–1738) who, in his *Elementa Chemiae*, rescued chemistry from these false guides and directed it into the true path of experimental research. He was one of the greatest figures in the transition period of chemistry, between the time of Winthrop and that of Jefferson, when old theories were being tested by the light of new knowledge. Boerhaave's practical methods of instruction attracted students from all parts of Europe, and his book, owing to its clarity and fullness of treatment, exercised through its numerous editions and translations a wide influence for over half a century. It appealed especially to those who were interested in the applications of chemistry to agriculture.

It was in 1744, the year after Jefferson's birth, that Peter Shaw published the first edition of his English translation of Boerhaave's treatise under the title *A New Method of Chemistry*, a work that was instrumental in extending Boerhaave's influence to the English colonies of North America. This is indicated by a reference in *The Pennsylvania Gazette* for August 12, 1756,

to the courses of study at the newly established College and Academy of Philadelphia where companion courses are listed in agriculture and in Shaw's translation of Boerhaave's *Chemistry*.

Boerhaave's efforts to raise chemistry into the rank of a leading science met with considerable opposition. Chemistry was regarded by many prominent naturalists of the eighteenth and nineteenth centuries as a servile upstart science, wholly unworthy of a place among the so-called liberal arts, and this was an opinion which Senebier, Sprengel, Liebig, and other chemists felt obliged to resist for over a century. The supercilious attitude of many scientific men toward chemistry during its early formative period is indicated by the following anecdote which Jefferson relates of the great naturalist Buffon in a letter, written in July 1788, from Paris during his residence in that city as Minister to France:

Speaking one day with Monsieur de Buffon, on the present ardor of chemical inquiry, he affected to consider chemistry but as cookery, and to place the tools of the laboratory on a footing with those of the kitchen. I think it, on the contrary, among the most useful of sciences, and big with future discoveries for the utility and safety of the human race. It is yet, indeed, a mere embryo. Its principles are contested; experiments seem contradictory; their subjects are so minute as to escape our senses; and their result too fallacious to satisfy the mind. It is probably an age too soon to propose the establishment of a system. The attempt, therefore, of Lavoisier to reform the chemical nomenclature is premature.

This passage not only reveals the somewhat contemptuous opinion of chemistry that was prevalent in the late eighteenth century but it is an excellent illustration of the much more favorable conception of this science which Jefferson himself had formed in the course of his scientific reading. His view of the future of chemistry, as here expressed, shows him to have been a progressive independent thinker and yet his opinion, formed in the midst of the heated controversy between the rival systems of Lavoisier and of the phlogistic school of Stahl, was highly conservative. The establishment of a new system of chemistry, which Jefferson thought to be probably an age distant, occurred actually within a year after he made this statement, with the publication in 1789 of Lavoisier's epoch-making two volume *Traité élémentaire de chimie*—one of the books that Jefferson added to his scientific library at Monticello.

It will be useful, at this point, to consider a few of the large number of chemical books in Jefferson's library that have a more or less direct relation to agriculture. The earliest of these was Francis Home's *Principles of Agriculture and Vegetation* published in 1757. It is the first example of a book devoted exclusively to a consideration of the applications of chemistry to agriculture and might well have been entitled "Principles of Agricultural Chemistry" had this term been then in use. The designation "Agricultural Chemistry" for the field covered by Home's book was not introduced, however, until nearly a half-century later when the German chemist Hermbstädt in 1804 first recognized its status as an established science by applying to his new journal the title *Archiv der Agriculturchemie*. Home in the introduction of his *Principles of Agriculture and Vegetation* proclaimed the birth of this new science in the following words:

The principles of all external arts must be deduced from mechanics, or chymistry, or both together. Agriculture is in the last class; and though it depends very much on the powers of machinery, yet I'll venture to affirm, that it has a greater dependence on chymistry. Without a knowledge in the latter science, its principles can never be settled. As this science is but of late invention and has not been cultivated with that regard to utility and the improvement of trades and manufactures, as it ought and might, agriculture is hardly sensible of its dependence on it. The design of the following sheets is to make this appear; and to try how far chymistry will go in settling the principles of agriculture.

It is probable that when Jefferson read this passage he was not conscious of the fact that it was again his privilege to witness the faint dawn of a new branch of science. Home was a phlogistonist, the same as Scheele, Priestley, Ingen-Housz, Macquer, and many other chemists whose works were owned by Jefferson. He also possessed the works of Lavoisier, Foureroy, Berthollet, and Guyton de Morveau, the chief representatives of the antiphlogistic school and the authors of the new "Chemical Nomenclature" which, although regarded by Jefferson at the time of publication as premature, was speedily

adopted by nearly all the leading chemists of Europe.

The phlogistonists and their opponents were equally interested in the applications of chemistry to agriculture. Jefferson, during his residence in Paris, was a close observer of the conflict of ideas between these rival schools, which in its last stages resolved itself chiefly into a mere quibbling about the meaning of words. Substitute hydrogen for phlogiston, oxygen for dephlogisticated air, nitrogen for phlogisticated air, and carbon dioxide for fixed air and, so far as plant chemistry is concerned, the two schools of chemical philosophy were in substantial agreement. Jefferson, who had a profound dislike for theoretical speculations, took no interest and no side in this great historic controversy. The practical application of chemistry to the needs of farming, cookery, and domestic industries was all that interested him. This attitude is reflected in many pages of Jefferson's voluminous correspondence, more especially in his letters to chemical friends in acknowledgment of books that they had published. Thus in a letter to Dr. Thomas Ewell, printed in the preface of his *Elements or Principles of Modern Chemistry*, Jefferson wrote in August 1805:

Of the importance of turning a knowledge of chemistry to household purposes, I have been long satisfied. The common herd of philosophers seem to write only for one another. The chemists have filled volumes on the composition of a thousand substances of no sort of importance to the purposes of life.

This tendency to evaluate chemistry solely from the utilitarian viewpoint is indicated in another letter that Jefferson wrote in July 1812 to Dr. Thomas Cooper in acknowledgment of a copy of his *Introductory Lecture to a Course of Chemistry*.

You know the just esteem which attached itself to Dr. Franklin's science, because he always endeavored to direct it to something useful in private life. The chemists have not been attentive enough to this. I have wished to see their science applied to domestic objects, to malting, for instance, brewing, making cider, to fermentation and distillation generally, to the making of bread, butter, cheese, soap, to the incubation of eggs, etc. And I am happy to observe some of these titles in the syllabus of your lecture. I hope you will make the chemistry of these subjects intelligible to our good house-wives.

Jefferson's hope for the establishment of

a household chemistry was not fully realized in America until fifty years after his death, when through the energy and perseverance of Mrs. Ellen H. Richards a "Woman's Chemical Laboratory" for instruction and research in this field was first created at the Massachusetts Institute of Technology in 1876. The accomplishment of this ideal of Jefferson in the centennial year of his Declaration of Independence is a coincidence that is symbolic in more ways than one.

The strong emphasis placed by Jefferson upon the practical values of chemistry and other sciences represents an attitude of mind that was shared by Franklin, Adams, and many other founding fathers, whose outlook was prompted by the requirements of a new country where immense natural resources were awaiting development.

Jefferson's almost exclusive regard for utility is indicated also by the large number of English, French, and Italian chemical books in his library, which he classified under the designation of Technical Arts—such works, for example, as Richardson's *Philosophical Principles of Brewing*; Knight's *On the Apple and Pear, Cider and Perry*; Krafft's *American Distiller*; Eale's *Cookery*; Parmentier's *Sur la Manière de faire le Pain, Le parfait Boulanger, Sur les Pommes de Terre, and La Fabrication des Sirops et des Conserves de Raisins*; Berthollet's *Elemens de l'Art de la Teinture*; Fabbroni's *Dell'Arte di fare il Vino*; and various tracts on making potash, maple sugar, and other domestic farm products. These are only a few of the numerous technological works that interested Jefferson in the management of his large Virginia estates, which from their isolated location were obliged to be largely self-sufficient in supplying the needs of his family, domestics, tenants, and slaves.

It must be remembered, however, that Jefferson's interests in domestic agricultural industries were more national than personal. During the period of his ministry to France between 1784 and 1789 he acquired from contacts with European science, agriculture, and industry information that was of such value to his home people that he has been aptly called the scientific scout of America. He made tours of inspection through south-

ern France, northern Italy, and western Germany, during which he devoted special attention to such agricultural chemical industries as the fermenting of wine, the expression of olive oil, the milling of rice, the curing of hay, and the making of butter and cheese. Jefferson's detailed description of the process of manufacturing Parmesan cheese at Lodi, Italy, in April 1787 particularly interested the present author, as during his visit to the Experimental Institute for Cheese-making at Lodi in April 1930 he saw processes almost identical with those described by Jefferson 143 years before.

From this account of Jefferson's general attitude towards the relations of chemistry to agriculture it will be interesting to consider some of his opinions with regard to farming practices on his own estate at Monticello and to test the validity of these opinions, so far as possible, by the findings of modern agricultural chemistry.

In Jefferson's tabular estimate of the annual exports from Virginia before the Revolutionary War (as given under Query XX of his *Notes on Virginia*) tobacco is listed first with a value of \$1,650,000, wheat second with a value of \$666,666 $\frac{2}{3}$, and Indian corn third with a value of \$200,000. Tobacco, Indian corn, and wheat were all grown at Monticello, at one time or another, the acreage given to each depending to a considerable extent on market conditions. More references to tobacco and tobacco culture are contained in Jefferson's writings than to any other crop, and we will therefore take his attitude towards the cultivation of tobacco as the starting point in our consideration:

It is a culture productive of infinite wretchedness. Those employed in it are in a continual state of exertion beyond the power of nature to support. Little food of any kind is raised by them; so that the men and animals on these farms are badly fed, and the earth is rapidly impoverished. The cultivation of wheat is the reverse in every circumstance. Besides clothing the earth with herbage and preserving its fertility, it feeds the laborers plentifully, requires from them only a moderate toil except in the season of harvest, raises great numbers of animals for food and service, and diffuses plenty and happiness among the whole.

This passage, among many others that might be quoted, indicates how strongly Jef-

erson regarded food production as the main purpose of agriculture. He held that tobacco-growing should be discontinued because it was not a food-plant and because it was the greatest robber of the soil fertility that belonged to food-producing crops such as wheat.

For many years Jefferson grew no tobacco at Monticello, but the high increase in its price at the close of the century obliged him to revoke temporarily his proscription against this crop. In a letter to President Washington dated June 1793, supplying information for Arthur Young, Jefferson has more to say about tobacco culture:

Good husbandry with us consists in abandoning Indian corn and tobacco, tending small grain, some red clover following, and endeavoring to have, while the lands are at rest, a spontaneous cover of white clover. I do not present this as a culture judicious in itself, but as good in comparison with what most people there pursue. . . . The highlands, where I live, have been cultivated about sixty years. The culture was tobacco and Indian corn as long as they would bring enough to pay the labor. Then they were turned out. After four or five years rest they would bring good corn again and in double that time perhaps good tobacco.

Jefferson's opinion as to the great impoverishment of the soil by tobacco was based entirely upon field observations of decreasing yields. The length of the time of fallow, or rest, before good crops could be obtained again—eight to ten years for tobacco, four to five years for corn, and one to three years for wheat—seems to have been his chief measure of the comparative depleting effects of these crops. He had in fact few other means of making an estimate. The role of the mineral constituents of the soil in plant nutrition was entirely unknown to Jefferson. It was not until 1842, sixteen years after Jefferson's death, that Wiegmann and Polstorff published their important research *Ueber die anorganischen Bestandtheile der Pflanzen*, in which it was shown that when grown in a fertile soil tobacco removed 18.20 per cent of its dry weight in mineral matter, clover 10.66 per cent, barley 6.40 per cent, oats 5.07 per cent, and buckwheat only 3.63 per cent.

Exact information as to the amounts of potassium, calcium, magnesium, phosphorus, sulfur, and other necessary mineral elements

that removed by corn. The general average for all six elements indicates that tobacco has a depleting effect three and a half times that of wheat and two and a third times that of corn. The method of calculation is open to some criticism and is not rigidly exact, but the values found are in good agreement with Jefferson's estimate of the time required for land to lie fallow before good yields of the three crops are regained, viz., eight to ten years for tobacco, four to five years for corn, and one to three years for wheat. The agreement cannot be regarded as accidental. Jefferson's estimates were based upon careful observations of his own and the general testimony of other planters.

Jefferson knew absolutely nothing about the chemical, physical, and biological factors of the soil that during the unproductive fallow periods promote the unlocking of plant nutrients from their nonavailable combinations. He believed the atmosphere to be the active agent in restoring fertility to worn out lands, being a follower in this, as in other particulars, of his friend John Taylor, whose series of agricultural essays, entitled *Arator*, was the guide of many Virginians. In addition to fallowing, Jefferson recommended, as means for improving the productivity of the soil, the use of manure, crop rotation, and the cultivation of protecting leguminous crops, such as peas, clover, and vetches. In a letter to an unknown correspondent written from Philadelphia in March, 1798, Jefferson had this to say regarding the value of the cow-pea:

It is very productive, excellent food for man and beast, awaits without loss our leisure for gathering, and shades the ground very closely through the hottest months of the year. This with the loosening of the soil, I take to be the chief means by which the pea improves the soil. We know that the sun in our cloudless climate is the most powerful destroyer of fertility in naked ground and therefore that the perpetual fallows will not do here, which are so beneficial in a cloudy climate.

Beyond attributing the chief value of the pea to its loosening the soil and protecting it against the injurious radiations of the sun, Jefferson was unable to go. It was not until 1838, twelve years after Jefferson's death, that Boussingault demonstrated that peas and clover possessed the power of assimilat-

ing nitrogen from the air and forty-eight more years had to elapse before Hellriegel and Wilfarth showed this power to be localized in the root nodules of these leguminous plants. Thus was established, in ways that Jefferson could not foresee, the truth of his statement that "The atmosphere is certainly the great workshop of nature for elaborating the fertilizing principles and insinuating them into the soil."

The sciences of human and animal nutrition, so important to agriculture and the national welfare, were practically nonexistent in Jefferson's time, and upon these subjects he was no further advanced than any of his contemporaries. His sole consideration in selecting rations seems to have been the supposed needs of his soil. This is indicated in a letter written in 1794, to his friend John Taylor, to whom Jefferson remarked:

The first step towards the recovery of our lands is to find substitutes for corn and bacon. I count on potatoes, clover and sheep. The two former to feed every animal on the farm except my negroes and the latter to feed them, diversified with rations of salted fish and molasses, both of them wholesome, agreeable and cheap articles of food.

This was perhaps only a passing thought of Jefferson (thrown out at random like so many of his observations) for the winter feeding of his farm animals and slaves when fresh vegetables and fruits were lacking, but neither Jefferson nor John Taylor, nor any other agriculturist of the year 1794, had a sufficient knowledge of human nutrition to estimate the inadequacy of a diet consisting solely of mutton, salted fish, and molasses. The science of nutrition had to wait over thirty years after Jefferson's death before light began to dawn on this important field.

Much more might be said with regard to the agricultural-chemical validity of other farm practices of Jefferson, but we must pass them over in order to say just a word about his views regarding the place that chemistry should occupy in the teaching of agriculture. This was a subject that had long concerned Jefferson in mapping out the courses of study for the new University of Virginia, which he had established at Charlottesville near his Monticello home.

As early as January 1800 Jefferson re-

quested his friend Dr. Joseph Priestley, the eminent English chemist, to submit suggestions about courses of study for such an institution as he had in mind. In answer to this appeal Priestley sent Jefferson an outline of literary and scientific courses of study for a faculty of nine professors. Priestley's scheme is interesting because the professor of chemistry is designated by him to include the theory of agriculture in his course of chemical instruction. The grouping of agriculture with chemistry in this outline is an evidence of the growing realization, both in Europe and America, that agriculture was more closely concerned with chemistry than with any other science. Jefferson seems to have been of the same opinion, for in the report of the Commissioners of the University of Virginia to the State Legislature (August 1818), which was written by Jefferson, it is stated: "Chemistry is meant, with its other usual branches, to comprehend the theory of agriculture." The same thought is expressed also in a letter, written only two months before his death to Dr. John P. Emmet, Professor of Natural History at the newly established University of Virginia, in which he suggested that Emmet blend Rural Economics with Chemistry, Botany, and Zoology, and that in his year's course of studies he devote one dozen lectures each to Botany, Zoology, Mineralogy and Geology, and eight dozen to Chemistry. Chemistry was thus allotted twice as much time as was given to the other four sciences combined. While the impending death of Jefferson prevented the execution of any such apportionment of studies as this in his new university, his suggestion remains as an evidence of the predominant part that he believed chemistry was destined to play in the future of agricultural science.

Jefferson's belief in a greater realization of the importance of chemistry to agriculture was soon to be abundantly confirmed, for at the very time he wrote his letter to Emmet a young professor at the University of Gies-sen in Germany was beginning research work in agricultural chemistry that was soon to exert a profound influence on the future of this science. He was Justus Liebig, whose book entitled *Organic Chemistry in its Applications to Agriculture and Physiology*, published in 1840, did more to revolutionize the art of husbandry than any other treatise on the subject. The doctrines promulgated by Liebig, in the various editions of this book and in the teachings of the hundreds of pupils who flocked to his laboratory from all parts of the world, set waves of progress in motion that still continue to be felt.

Jefferson had unbounded faith in the future of chemistry and of all other sciences that were related to agriculture and to the prosperity of the republic that he had been so instrumental in helping to found and whose interests, in over thirty years of public office, he had striven so zealously to promote. His confidence in the future advancement of science is well expressed in a letter that he wrote from Monticello to his friend Dr. Benjamin Waterhouse in March 1818, nine years after his retirement from the presidency.

When I contemplate the immense advances in science and discoveries in the arts which have been made within the period of my life, I look forward with confidence to equal advances by the present generation and have no doubt they will consequently be as much wiser than we as we than our fathers were.

With this message of high confidence and optimism our present discussion of some of Jefferson's relations to Agricultural Chemistry may very fittingly be brought to a close.

GEOMETRY AND EXPERIENCE*

By N. A. COURT

STUDENTS who gather for their first lesson in geometry know already a good deal about the subject. They are familiar with certain shapes that textbooks on geometry call parallelepipeds, spheres, circles, cylinders, which the students would call boxes, balls, wheels, pipes. Notions such as point, line, distance, direction, and right angle are quite familiar and clear to them, in spite of all the difficulties learned mathematicians profess to encounter when they try to clarify or define these concepts.

The question arises, how was this store of knowledge gathered, how was this information acquired? The empiricists maintain that geometrical knowledge is the result of the experience of the individual in the world surrounding him. However, the universal acceptance of the basic properties of space lead the apriorists to the conclusion that these spatial relations are innate, that they constitute a fundamental characteristic or limitation of the mind which cannot function without it or outside of it. The invention of non-Euclidean geometry has done considerable damage to the solidity of the apriorist armor but has not eliminated the debate between the two schools of thought.

During the present century the eminent French sociologist Émile Durkheim (1858-1917) advanced an intermediate thesis. The source of our geometric knowledge is experience. However, at a very early stage of civilization this individual experience is pooled and codified by the group, owing to social necessity and in order to serve social purposes. Our basic geometric knowledge is thus a social institution. It is this social function of geometry that accounts for the fact of its universal acceptance, for the inability of the individual to act contrary to it, for the mind to reject it.

It is universally agreed that the actual experience of living is the basic factor in the process of accumulating information of the kind that we call spatial or geometrical.

* From an address before the Mathematical Colloquium, University of Oklahoma, May 1944.

This in turn amounts to saying that we come into possession of this information through our senses. Such being the case, the question naturally comes to mind, which of our senses is it that performs this function?

The sense of hearing helps to acquire the notion of direction. To a lesser degree this is also true of the sense of smell. The sense of taste need hardly be mentioned in this connection. The sense of sight and the sense of touch remain. It does not take much effort to see that these two senses play the dominant part in the shaping of our geometrical knowledge.

The sense of touch, considered in its broader aspect of including also our muscular sense, supplies us with information as to the shape of things. It is also our first source of information about distance. By touch we learn to distinguish between round things and things that have edges, things that are flat and things that are not flat. It is the sense of touch that conveys to us the first notions of size. This object we can grasp with our hand, and this other cannot be so grasped; it is too big; this object we can surround with our arms, this other we cannot; it is too big.

These examples imply measuring, and the measuring stick is the size of our hand, the length of our arm, and, more generally, the size of our body. The whole environment that we have created for ourselves in our daily life is made to measure for the size of our body. That the clothes we wear are adapted to the size of our body and our limbs goes without saying. But so is the chair we sit on, the bed we sleep in, the rooms and the houses we live in, the steps we climb, the size of the pencil we use, and so on, without end. We take it so much for granted that things should fit our size that we are startled when they fail to conform to the adult standard, as, for example, in the children's room of a public library where the chairs are tiny and the tables very, very low. The legendary robber Procrustes, of ancient Greece, had his own ideas about matching the sleeper and

the size of the bed. He made his victims occupy an iron bed. If the occupant was too short, he was subjected to stretching until he reached the proper length. If, on the contrary, the helpless victim was too tall he was trimmed down to the right size, at one end or the other. Hebrew writers placed this famous bed in Sodom, and it was one of the iniquities that caused Sodom's destruction, by a "bombardment from the air."

In many cases the fact that things are made on the "human scale" may be less immediate but is no less real. The clock on the wall has two hands, whereas, strictly speaking, the hour hand alone should be sufficient. Owing to the limitations of our eyesight, we cannot evaluate with sufficient accuracy fractional parts of an hour by the use of the hour hand alone, unless the face of the clock was made many times larger than is customary. But then the clock would become an unwieldy object, out of proportion to the other objects around us made to the "human scale."

The comparison of the size of objects surrounding us with the size of our body is not just a kind of automatic reflex but is a deliberate operation as well. When in the course of our cultural development the need arose for greater precision in describing sizes and for agreement upon some units of length, we turned to our body to provide the models. The length of the arms and of the fingers, the width of the hand, the length of the body and of the legs all served that purpose at one time or another, at one place or another. The yard is, according to tradition, the length of the arm of King Henry I. The origin of the "foot" measure requires no explanation, and we still "step off" lengths.

The sense of vision is the other great source of geometrical information. To a considerable extent this information overlaps the data furnished by the sense of touch. Sight informs us of the difference in sizes of objects around us. Sight supplements and extends the notion of distance that we gain through touch. Sight tells us of the shape of things, and on a much larger scale than touch does. But sight asserts its supremacy as a source of geometrical knowledge when it comes to the notion of direction. Moreover, sight tells us "at a glance" which object is closer, which is farther, which is in front

and which is behind, which is above and which is below. Sight is supreme in telling us when objects are in the same direction from us, when they are in a straight line. When we want to align trees along our streets, we have recourse to sight. The fact that light travels in a straight line is one of the main reasons for the dominant position the straight line occupies in our geometrical constructs. I realize that some learned persons will smile indulgently at the statement that a ray of light is rectilinear. I will, nevertheless, stick to my assertion as far as our terrestrial affairs are concerned, whatever may be true of light on the vaster scale of the interstellar or intergalaxian universe.

Up to this point the geometrical knowledge I have mentioned is the kind familiar to "the man in the street." Let us now turn to the systematic study of the subject, to the science of geometry. Are both empirical sources of geometrical knowledge reflected in systematic geometry? Is it possible to classify geometrical theorems on that basis?

If we examine Euclid, we see that he leaned heavily towards tactile geometry, or the geometry of size. His main preoccupation was to establish the equality of segments and angles, to prove the congruence of triangles. The method of proving triangles to be congruent consists in picking up one triangle and placing it on the top of the other, which implies that the moving triangle does not change while it is in motion. This possibility of rigid motion was much insisted upon by Henri Poincaré (1854-1912) and is now considered by mathematicians to be the characteristic property of the geometry of size, or, to use the professional term, of metric geometry. Euclid's is thus metrical geometry exclusively, or nearly so. This is not at all surprising, since metrical geometry is the geometry of action, the geometry that builds our dwellings and makes our household utensils. The very origin of Euclid's geometry is supposed to be connected with the parcelling out of plots of land in Egypt after the recession of the flood waters of the Nile.

Euclid did not know that his was metrical geometry. To him it was just geometry, for he knew of no other kind. Neither did his

successors, in spite of the fact that they added to Euclid's *Elements* a considerable number of geometric propositions which in their nature are visual and not metric. There are numerous such propositions, some of them of fundamental importance, in the collection of Pappus, a Greek author of the third century of our present era. A systematic study of visual geometry had to wait for a millenium and a half before it found its apostle and high priest in the person of the French army officer Jean Victor Poncelet (1788-1867), the father of projective geometry.

Consider any geometrical figure, say a plane figure (triangle) F (Fig. 1), for the sake of simplicity, and let S be a point (representing the eye) not in the plane of figure F . Imagine the lines joining every point of figure F to the point S . Now, if we place a screen between S and figure F , everyone of these lines will mark a point on the screen, and thus we obtain a new figure F' in the new plane, the image of figure F .

If we compare the two figures F and F' , we notice some very interesting things. The figure F' in general will be different from F . It has suffered many distortions. If A, B are two points in F and A', B' are their images in F' , the distance $A'B'$ is not equal to the distance AB , as a rule, and may be either smaller or greater than AB , and this alone deprives the figure F' of any value in the study of the figure F from a metrical point of view. There are, moreover, many other distortions of various kinds. But some characteristics of F always reappear in F' . Of these the most important is that a straight line p of F has for its image in F' a straight line p' , and consequently any three points A, B, C of F that lie on a straight line in F will have for their images in F' three points A', B', C' that also lie in a straight line. If two lines p and q are taken in F , their images in F' are two straight lines p' and q' , but the angle $p'q'$ is not equal to the angle pq , as a rule, and may be either smaller or larger than pq . In particular, the images of two parallel lines are not necessarily parallel, and the images of two perpendicular lines are not necessarily perpendicular.

If we call figure F' the projection of figure F from the point S , we may say that projec-

tion preserves incidence and collinearity. The systematic study of projective geometry, or visual geometry, is the study of those properties of figures that remain unaltered by projection, just as it may be said of metrical geometry that it is the study of those properties of figures that remain unaltered in rigid motion.

From the point of view of the theory of knowledge it is of great significance that the distinction between tactile geometry and visual geometry was not noticed by either philosophers or psychologists. Only after the patient labors of mathematicians created the doctrine of projective geometry did the distinction come to light. The credit for having pointed out this distinction goes to Federigo Enriques, Professor of Projective Geometry at the University of Rome.

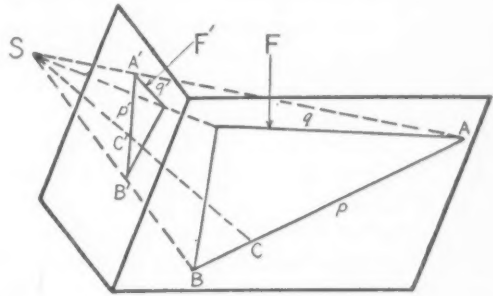


FIG. 1. *IN RE* PROJECTIVE GEOMETRY

In the study of the sources of our geometrical knowledge too little attention is accorded to our own mobility, to our ability to change places. Even the range of our knowledge due to touch is considerably increased by our ability to move our arms. In connection with our visual information our mobility is of paramount importance. To mention only one point, the shape of an object depends upon the point of view, or the point of observation. It is our ability to change places that makes it possible for us to eliminate the fortuitous features from our observations.

As has been mentioned before, our tactile and visual information do not cover the same ground, but they overlap to a considerable extent and thus complement each other. But do they always agree? If a person drives his car over a stretch of straight road, he observes that the road is of the same width all

along. He knows it to be so by comparison with the size of his car and by comparison of the size of his car with his own size; in other words, it is a tactile fact. Now, if he turns around and looks at the road just traversed, he sees "with his own eyes" that the road is getting narrower as it extends back into the distance and seems to vanish into a point. These two items of information on the same subject contradict each other. Which of them is true and which is false? Which of them do we accept and which do we reject? Above all, how do we go about telling which to accept and which to reject?

When one puts a perfectly good spoon into a glass of water, he sees that the spoon is unmistakably broken, or at least bent at a considerable angle. He takes the spoon out, and it is as good as it was before he put it in. He runs his finger along the spoon while it is in the glass and feels that it is as straight as ever. But when he looks at it, there is no doubt that the spoon is bent; contradictory testimony of two different senses. Again the question arises, which of the two pieces of information do we accept, and on what ground do we make our choice?

A long time ago I read of a lake where the water was so clear that on a bright moonlit night it was possible to see the fish asleep on the bottom of the lake. Devotees of fishing would take advantage of this situation and go out in a boat, as quietly as possible, to the middle of the lake and then try to catch the fish by striking them with a har-

poon. It was explained in my reader that aiming the harpoon at the spot where a fish was seen would spell disastrous failure and that successful practitioners of the sport would know the spot at which to aim, although the fish was seen to be elsewhere.

The moral of this fish story is of great importance. In the case of the road and in the case of the spoon we all repudiate the testimony of our eyes and accept the verdict of the sense of touch. We do so whenever the tactile and the visual testimonies are in disagreement. But why?

The answer to this puzzling question may be found in the activity of man. Moreover, his activities are purposeful and must be co-ordinated so as to achieve success. Now, man's organs of activity, his hands, are also the main organs of touch. Man has thus developed a close co-ordination between his touch and his actions. At short range, he has implicit faith that his actions will be fruitful if he relies on the data furnished by touch. Visual data concern objects at a distance and serve well as a first approximation. They are good in most cases but are always subject to control and check. If light sees fit to indulge in such vagaries as reflection, refraction, and mirages, so much the worse for light. My fish story points to just that moral. Sight leads us to the fish. But if we want to act on it successfully, we must subject this information to the necessary correction as learned by touch. Otherwise we shall have no fish to fry.

METALLURGY AND THE WAR*

By ZAY JEFFRIES

No crystal ball was required to predict that vast quantities of metals would be consumed in a world war. It was equally obvious that in a modern world war the quality factor must go hand in hand with quantity. When the war broke out in Europe in 1939 the state of health of the metal industry in the United States was not too good. In tonnage, iron and steel account for more than 90 per cent of the metal production. The world metal situation is, therefore, reflected in the figures for steel. In 1929 we produced about 63,000,000 tons of steel ingots, which was 48 per cent of the world output. In 1939 we produced 52,000,000 tons, which was only 35 per cent of the world output. While the world production in 1939 was registering a new all-time high of 149,000,000 tons, or a gain of 17,000,000 tons over 1929, other countries—mostly European—gained 28,000,000 tons and we lost 11,000,000.

For military purposes metals are divided into three main classifications: (1) *Strategic*; (2) *Critical*; and (3) *Essential*. *Strategic* metals are necessary to the conduct of war and not available in sufficient quantities within the sphere of influence of a nation. *Critical* metals are necessary for war and available domestically, but may require conservation or distribution control in wartime. *Essential* metals are needed for war and considered to be available domestically in sufficient quantities for both war and essential domestic purposes.

When the war started in Europe the metals considered to be "Strategic" here were antimony, chromium, manganese, mercury, nickel, tin, and tungsten. Aluminum and vanadium were classified as "Critical," and lead, magnesium, molybdenum, copper, platinum, zinc, iron, and steel were classified as "Essential." These classifications have undergone many and wholesale changes during the past few years. These changes constitute, in part, a reflection of unexpected and sometimes hectic situations.

Our metal industries were splendidly qualified to meet any ordinary increases in demand, and some groups even anticipated unusual increases. For example, the aluminum capacity was substantially increased, by private capital, and additional facilities were in process prior to the advent of plans for the Government-owned plants. The same was true of magnesium. But, as the production for war approached maximum, most of the metal industries had to expand substantially, and some needed fantastic increases.

The plans for aluminum called for an expansion in capacity of sevenfold and for magnesium, a hundredfold. While the plans for steel expansion were modest in percentage, in amount—10,000,000 tons annually—they called for a greater increase than that of all other metallic products combined.

Acute shortages appeared in 1941: First nickel and aluminum; then followed zinc, copper, magnesium, and even lead; finally, steel became short, and the expansion program began in a big way. Many nonmetallic materials were used in place of metals. These included, in part, plastics, rubber, glass, paper fabric, concrete, leather, and wood.

It was learned in the succession of shortages that substitutions of one metal for another were possible within rather wide areas, although certain metals were well-nigh indispensable for particular purposes. Substitutions were made on the basis of availability rather than on an economic basis. For example, it is not obvious that the heavy metal lead can be substituted for the light metal magnesium. When a shortage of the latter developed, however, lead-base alloy die castings were used in place of certain magnesium-base die castings.

Thus it was learned that, in general, an increase in the supply of one metal eased the whole metal shortage situation. This gave assurance that increased steel capacity, which could be accomplished cheaper and sooner than for other metals, would take care largely of the metal shortage problem. Increases

* Presented at the Autumn Meeting, National Academy of Sciences, Washington, D. C., Nov. 15, 1944.

were needed all along the line, however, in varying degree—partly to provide greater quantity but mainly to insure high quality of our metallic products.

Increased steel production made the problem of manganese supply critical. Not only is manganese needed in the manufacture of ordinary steel, but it is one of the valuable elements used in many alloy steels. There was insignificant production within the borders of the United States. The earliest program, therefore, concerned itself partly with manganese. There are low-grade deposits in the United States containing more than enough manganese to satisfy our war needs. It was necessary to choose the deposits that should be worked and to develop proper flow sheets for the recovery of this metal. This was a necessary precaution against the possibility of the shutting off of imports, even though large amounts of equipment and large expenditure of manpower would be required. These things were done, spearheaded by the Council of National Defense and the various successor organizations, including the Office of Production Management, the Supply Priorities and Allocations Board, and the War Production Board. The facilities for the domestic production of manganese were financed by the Government.

The steps taken to insure sufficient chromium were similar in nature to those taken for manganese.

The requirements for mercury were adequately taken care of by a price increase from \$90 a flask of 76 pounds to \$190 a flask. Under this price stimulus domestic producers added sufficient mercury to the imports to satisfy the demand.

There was no such possibility in the case of tin, because the deposits were not available. Special arrangements, therefore, were made to import ores of tin from Bolivia and treat them in a Government-owned smelter authorized for this purpose and built in Texas.

When Japan made her conquests in the Far East, the main tin production center of the world fell into her hands. We were fortunate in having a stock more than equivalent to one year's consumption, even at the expanded wartime rates. We needed to dig in, however, for the long pull, and this is

exactly what was done. The United States could expect to receive something on the order of 50,000 tons of tin yearly in the form of concentrates and pig tin, and it was known that a certain amount could be recovered from scrap. However, there seemed to be no possibility of providing the annual minimum of around 100,000 tons for wartime consumption. A concerted attack on the whole problem of tin supply and conservation was therefore made.

In the meantime other problems in connection with the metal supply were appearing. The National Academy of Sciences had been asked to advise the Council of National Defense on manganese, chromium, and tin problems. This work was later expanded to include advice on all metals and minerals and led to the organization of the Advisory Committee on Metals and Minerals. This group to advise the Office of Production Management was organized under the auspices of the Academy and the Research Council. Later, the National Defense Research Committee desired to have the Academy and the Research Council organize a group to help them on metals and minerals, and this was done through the organization of the War Metallurgy Committee. There were three main units: Research, Advisory, and Information Distribution Divisions. The War Metallurgy Committee, therefore, served both the Armed Services and the various civilian organizations dealing with war problems.

The scope of the work of the War Metallurgy Committee is broad. Major studies and reports have been made, for example, in connection with the following metals, minerals, and alloys: aluminum, alumina, antimony, asbestos, bauxite, beryllium, boron, brass, cadmium, cast iron, cement, chromium, clay, cobalt, copper, cryolite, diamond, graphite, iridium, iron, kyanite, lead, lithium, magnesium, manganese, mercury, mica, molybdenum, nickel, platinum, rutile, scrap metals, steel, tantalum, tin, topaz, tungsten, vanadium, zinc, and zirconium.

The work has related to raw materials, production processes, fabrication, development of alloys, heat treatment, conservation, substitution, chemical analysis, physical testing, welding, casting, and inspection.

Hundreds of metallurgists have been active

in these studies. The research activities comprise more than a hundred specific projects handled for the War Production Board or the National Defense Research Committee or directly for the Armed Forces. These projects include, among others, work on aircraft materials, armor-plate, heat-resistant alloys, alumina production, magnesium production, steel processes, conservation, and substitution. Over fifty groups are collaborating, including industrial, independent, and Government laboratories.

The operation of the advisory units of the War Metallurgy Committee is a fine example of how a democracy can share its peacetime knowledge to win a war. Much of this information is proprietary, and it literally represents an important part of the owner's capital. Much of it has been shared, with little regard for postwar consequences. More than two hundred advisory reports have been submitted.

The Armed Forces determined to a large extent the requirements for both the quantity and quality of metals. Industry, large and small, performed the great tasks of production and fabrication. The War Production Board and its predecessors had the main responsibility for bringing supply and demand into balance. Because the supply had to be increased quickly, and sometimes dramatically, it became open season for many with untried processes, marginal mineral deposits and, in general, for new ideas—by no means excluding those usually classified as “crackpot.”

While the War Metallurgy Committee was small in comparison with the producers and fabricators, or even the War Production Board, it nonetheless performed a valuable service. A compass and other navigation instruments are small in comparison with the size of a ship, and a governor is small in comparison with the size of an engine, but both have vital functions. The War Metallurgy Committee served as a compass to help keep the great metal program moving in the right direction, and it served as a governor to help keep the great machine from running wild.

The advisory surveys constituted the greater part of the service in the earlier part of the program. As might have been ex-

pected, they uncovered areas in which insufficient information could be found. The need for research projects was therefore ascertained, and for some time past and at present the research program is much more active than the advisory work. Both, however, move along together in harmony.

It should be noted that the metal shortages mentioned earlier were not caused by reduced supplies but by a greatly increased demand. In fact, the supplies were the greatest in history. Of all the metals tin alone is available in lesser amounts than before Pearl Harbor.

The manner in which we have adjusted ourselves to the lower tin supply is noteworthy. The electrolytic process of making tinplate is being expanded rapidly to take the place of the hot dip process, with a saving of about 50 per cent of tin per square foot of tinplate. The tin content of solders has been greatly reduced and, in many instances, eliminated entirely. Conservation in the utilization of tinplate and in alloys containing tin is widespread. More tin is being reclaimed from scrap, including tin cans, than in peacetime. As a result of all these things, neither the war nor the civilian economy is suffering much from lack of tin.

Strangely enough, the situation in copper has been one of the tightest. To make copper available for certain purposes for which there are no good substitutes, thousands of tons of silver owned by the Government have been used for bus bars and other electrical conductors. It is expected that this silver will be returned to the vaults after the war. Thus, much of Uncle Sam's available silver is now leading a double life. Even though it has sent thousands of tons of copper to the battle fronts, the silver is as valuable as before as a money base. It is also an example of how weird a war economy may become. In one of the new aluminum reduction potrooms equipped with silver bus bar electrical conductors, the value of the silver is greater than the value of the remainder of the plant.

An intensive development program on steel cartridge cases, to substitute for brass, has produced results sufficiently promising to afford comfort if copper and zinc are not available in sufficient quantities.

One of the great achievements, especially

from the standpoint of quality, is the expansion in the production of alloy steel. Electric steel furnace capacity alone is now about 5,000,000 tons a year, or around three times that of prewar capacity. The total alloy steel capacity is about 15,000,000 tons annually. One reason for the higher production is the extensive use of the N.E., or National Emergency, steels. These were devised for the purpose of conserving the supply of steel alloying elements. The amount of these elements in the scrap is carefully ascertained. Much of the scrap is a sort of iron-base "goulash." A fortunate circumstance makes this goulash suitable for the conservation of the alloying elements. It is found that small amounts of these elements, when present simultaneously in a given steel, produce substantially greater "hardenability" than that calculated from the effects of the same elements used singly. The principle is employed in making alloy steel from both scrap and new metal, resulting in a greater tonnage of alloy steel from the available alloying elements. The Iron & Steel Institute deserves much credit for leadership in the National Emergency steel program.

The effect of the war on the light metals aluminum and magnesium has, perhaps, been the most sensational. The dislocations from peace conditions have been great as compared with those of the other common metals.

The War Metallurgy Committee has taken a very active part in the aluminum expansion program. Both Research and Advisory Divisions have worked closely with the Aluminum and Magnesium Division of the War Production Board since 1941. Much of our aluminum ore, bauxite, was imported from Dutch Guiana, and the German submarines made transportation hazardous. Our domestic reserves of low-silica bauxite seemed wholly inadequate for a long war. Plans were made and put into effect to utilize our much larger reserves of high-silica bauxite, and a longer range program was planned to recover aluminum from clay, if necessary.

For decades it has been possible to recover aluminum from clay, but when low-silica bauxite containing more than 50 per cent

aluminum oxide is available at low cost, it is uneconomical to use a clay with, say, 35 per cent aluminum oxide and high silica. If it becomes necessary to use clay or some other other raw material because suitable bauxite is not available, then this can be done. It is desirable to know which clays to use and what are the most economical processes for treating them. This has been the subject of much investigation and research, and it can be confidently stated that in the future the United States can be made independent of foreign bauxite for war purposes. With present knowledge this independence can be had only at the expense of additional equipment and manpower.

The magnesium expansion is unusual, partly because vast quantities were required for purposes other than structural, namely, for incendiaries and pyrotechnics. The increased need for its structural uses is, however, imposing. It helps to make aluminum alloys stronger and, when used as magnesium-base alloys for certain aircraft parts, it saves weight.

One of the interesting features of the expansion program was the use of the ferrosilicon reduction process. Most of the increase was effected by the conventional process, including sea water as one source of raw material. Direct current electricity is required for this process. Because of the upped aluminum program, which also required direct current, it appeared that there would not be enough direct current to make the required amount of magnesium. By utilizing alternating current in the manufacture of ferrosilicon and by using the latter to reduce magnesium from burned magnesium limestone in a vacuum at high temperatures, the extra capacity was provided. Equipment for producing more than 100,000,000 pounds of magnesium per year by this process is now installed.

In general, the problems of metal supply were solved by a combination of the following: increased production, substitution, conservation, and restricted uses. The shortages were attacked on all these fronts simultaneously, with such success that these problems are now mostly a matter of history.

SCIENCE ON THE MARCH

THE NEW DIVISION OF HIGH-POLYMER PHYSICS OF THE AMERICAN PHYSICAL SOCIETY

The science of such materials as rubber, textiles, and pulp and paper has been expanding for decades. In the early stages of these studies the physical technologist developed tests and experiments for determining the mechanical and other physical properties of these materials in their bulk state and in products fabricated from them. In the study of the intrinsic character of the materials, the chemist has advanced the knowledge of the constitution and molecular structure to a remarkably high degree. In recent years there has been much interest in the correlation of these two bodies of knowledge, tending to emphasize the spacial arrangements of the submicroscopic elements, as well as the quantitative relations between molecular properties and the properties of the materials in bulk. For their unique efficacy in studies in these domains, the principles and experimental techniques of modern physics have received expanding recognition.

Concomitantly, the physicists engaged in research on these high polymeric materials have perceived a need for an organization that would provide improved opportunities for the exchange of information and ideas contributory to the attack on problems in the field of high-polymer physics. This need was brought into rather sharp focus when, with the entry of the United States into World War II, our supply of natural rubber was abruptly halted, and American industry turned to the large-scale production of synthetic rubbers, new and relatively unfamiliar materials. Under the impact of wartime urgency physicists in the rubber research laboratories of the country were called upon to accelerate their studies of the properties and fundamental behavior of the synthetic rubbers and to extend their research techniques to the newer types and formulations being produced. With the specialized field developing faster than text and reference books could be written and published, it became apparent that it was only to personal discussion with his colleagues that the re-

search worker could turn for inspiration. Similar developments, though perhaps not quite so rapid, had occurred over the span of recent years in physical research on textiles, plastics, and pulp and paper also.

It was logical that the physicists engaged in high polymeric research should consider the formation of a division in the American Physical Society to fulfill their needs. Petitions to the Council of the Society for the establishment of a division to be devoted to the physics of high polymeric materials were circulated during the fall of 1943. These activities culminated in a meeting held, under the chairmanship of Dr. Warren F. Busse and at the invitation of Society officers, at Evanston, Illinois, on November 12, 1943. That same day the Council, responding to the petitions and to a formal resolution adopted by the meeting, authorized a division to be devoted to High-Polymer Physics. Thus, within one year a second division of the Society had been launched, the Division of Electron and Ion Optics having been authorized on May 1, 1943 (Darrow, K. K., *THE SCIENTIFIC MONTHLY*, p. 570, Dec. 1943).

An Organizing Committee consisting of Council representatives (headed by Dr. K. K. Darrow as chairman) and members of the Society sponsoring the new Division (led by Dr. J. H. Dillon) was subsequently appointed by the President of the Society. The Committee went to work immediately on the precise formulation of the objectives of the Division, on drawing up By-laws, and making plans for the first meeting. Over 250 original members were enrolled in the Division by April 20, 1944. While the Division had had potential existence since its authorization, it was formally established at an Inaugural Meeting held conjointly with that of the Society at Rochester, New York, on June 23 and 24, 1944. This meeting, with its scientific program of twenty-two papers on physical research on rubbers, plastics, textiles, and high polymers in general, was generally recognized as a marked success.

The formal statement of the object of the Division, as incorporated in the By-laws, declares that object to be "the advancement

and diffusion of the knowledge of the physics of high-materials of any kind. Illustrative examples include rubbers, textiles, plastics, pulp and paper, paints and varnish, leather." The scope of the Division is envisioned as being sufficiently broad to embrace alike the interests of those working in academic, industrial, and governmental laboratories, whether these interests be focused on the fundamental physics of high polymer behavior or on the problems arising from the application of these materials to use by society. It is intended, however, that precaution be exercised to maintain the interests of the Division at a high scientific level, consistent with its relationship to the American Physical Society. It may be expected that as a result of the activities of the members and associates of this Division, High-Polymer Physics will emerge as a well-defined branch of the science of physics.

Any Fellow or Member of the American Physical Society may enroll in the Division of High-Polymer Physics. For those scientists and research workers who are not members of the Society, but who are interested and qualified in high-polymer science, the Division provides an associateship. Associates of the Division will receive announcements of, and may participate in, the activities of the Division, lacking only the rights to vote and to hold office.—W. JAMES LYONS, Division Secretary.

PERENNIAL MATHEMATICS

Mathematics is today enjoying an unprecedented popularity among grown-ups. This is due in large measure to public awareness of the part mathematics is playing in the present war. W. L. Laurence wrote recently in the "Science in Review" column of the *New York Times*: "In no previous crucial period in the world's history has mathematics played so vital a role. All our marvelous war weapons are basically the products of applied mathematics, which, in turn, is the offshoot of pure mathematics."

According to Dr. Frank B. Jewett, president of the National Academy of Sciences, mathematics has played an important part in the development of the gyroscope, the automatic pilot and bombsight, has been used to improve the accuracy of gunfire, and has

helped to solve problems met in the design of big battleships and aircraft carriers. Mathematics has been applied to the study of vibrations, such as wing flutter in airplanes, and to elasticity problems, such as the expansion of a gun barrel, the twist of a ship's propeller shaft, or the bending of metal plates in aircraft during flight.

Without attempting to list all, or even a large portion, of the fields where mathematics has proved to be so essential, let us examine one case where well-established pure mathematics has found new uses. Everyone knows that a great deal of mathematics has always been required to design a modern airplane. Also, it has been generally recognized that the mass production of airplanes, calling for "correct detail parts which go together without reworking in the final assembly," has posed tremendous new problems for the aircraft companies.

An engineer for one of these companies has stated recently that solid analytic geometry can well be termed "mass production mathematics" as contrasted with the older methods involving trigonometry and descriptive geometry. For amplification of this statement one can consult several textbooks that have been published during the past year. Furthermore, an examination of these shows that in addition to analytic methods for the engineering, lofting, and tooling of aircraft, use is now made of the methods of synthetic projective geometry, one of the "purest" branches of mathematics. This branch is so "pure" that of late years it has been taught only occasionally and to very small groups of students, usually those preparing for graduate study.

But the interest in mathematics on the part of many laymen began long before the war started. *Mathematics for the Million* by Hogben was published in 1937. Although this book was not the first popular book on the subject, its influence has been very great. It has been reprinted many times and has been translated into eleven or twelve different languages. Because of its sales record (probably well over a million copies by now), it has been called the *Gone with the Wind* of mathematics.

Certainly one reason for the success of this book lies in the manner in which the author

shows the uses of each bit of mathematics that he develops. Too often in the old days, when mathematics was taught primarily as a mental discipline, little or no attention was paid to applications or to connections with other fields of learning. Fortunately today the wide-awake instructor has available a wealth of material to use for class illustrations or as collateral reading.

E. P. Northrop, the author of *Riddles in Mathematics—A Book of Paradoxes* (published in March, 1944, and reprinted two months later), gives an additional reason for popular interest in mathematics. "On the other hand, the abstract aspect of mathematics is beginning to attract a large following of people who, weary of the complexities of the human equation in everyday activities, turn in their leisure to the simplicities of the mathematical equation." Plenty of books are now available for such people, books that make very little demand on foundation material, but books which do require careful and attentive reading.

But what of the popularity of mathematics with our young people? Here, frankly, the score is not so good. Thousands of them were certainly caught short mathematically when the war started. During the easygoing thirties, mathematics gradually ceased to be a required subject in most schools and colleges. Since it is generally regarded as a "hard" or difficult subject, students, following the line of least resistance, failed to elect it, frequently on the advice or with the blessing of their advisers. Since the war began, many of our young men have had a concentrated dose of mathematics rammed down their intellectual throats in a hurry. How they will react to this experience remains to be seen. Doubtless some of them will never again want to see a book dealing with mathematics, others may have found out that mathematics is not so bad after all, and a few may even have discovered a passion for it.

The outlines of postwar education are certainly not clear at the present time. But of this much we can be certain: Mathematics as a school subject, far from dying out, will continue to be taught. And mathematics—the oldest of the sciences—will continue to supply the tools and to lead the way for the

other sciences. Also, it will continue to enrich logic and philosophy and other broad areas of human understanding.—HAROLD L. DORWART.

AIRCRAFT FROM THE SEA

Britain, during the present war, has discovered that if the sea that laps her boundaries on every side is no longer itself a certain bulwark against invasion, it remains a material vital to her defense. For it is from the sea that Britain has been obtaining the magnesium that is so important a part of those strong but light alloys from which aircraft are built. The Royal Air Force today flies largely with the aid of magnesium thus extracted.

To the ordinary man, sea water is simply "salt"; but there are a great many chemicals dissolved in the water besides sodium chloride, or common salt. The substance so valuable to Britain during the war has been magnesium chloride, present in sea water to the extent of 1 part in 800. This may seem a trifling amount, but the sea is vast and even a cubic mile of sea water contains many thousands of tons of the metal. With Germany in possession of the minerals from which most of the world's magnesium had been obtained, Britain decided to turn to the sea and built two plants for magnesium extraction in the greatest secrecy. It is only recently that the existence of these "factories," handling 11,000,000 gallons or more of sea water every day, has been revealed.

The chemistry of turning the magnesium chloride dissolved in sea water into the shiny white metal that enters so largely into the construction of aircraft, incendiary bombs, and many other weapons is fairly simple. The magnesium is thrown out of solution by adding lime, which forms an insoluble hydroxide. This is filtered off, dried, and then taken to other factories where the magnesium metal is made in the usual way. It is worth recalling that rapidly improved methods of manufacture have resulted in magnesium changing from a laboratory curiosity into a metal cheap enough for use in bulk. In thirty years the cost has fallen from \$4.00 a pound to less than twenty cents a pound.

Although the chemical processes involved are simple, the engineering difficulties are

considerable because of the great scale on which the operations must be carried out. Wartime erection of these plants in a matter of months was a remarkable feat of chemical engineering. Various considerations had to be taken into account in choosing a site for the operations. The amount of magnesium in the sea varies from place to place, and a point was chosen where the magnesium content was highest. Arrangements had then to be made to ensure that currents and tides would carry away the discharged water—to have the many millions of gallons again drawn back into the plant would have been fatal. Waste water must be carried some distance from the intake.

The water pumped into the plant through large pipes is first filtered and then passed to a tank where the finest particles of insoluble matter are removed. It passes to other tanks for precipitation by the addition of finely powdered lime. These tanks are very large—they have several times the capacity of a large swimming pool—and when the precipitated hydroxide has settled, the water is drawn off for return to the sea. The precipitate is scraped up and carried to rotary kilns for drying and subsequent conversion into magnesium.

In actual practice the chemical used for precipitation is not pure lime but a mixture of lime and magnesium oxide obtained by calcining the mineral dolomite, which is obtained from a conveniently situated quarry. The lime reacts with the magnesium chloride dissolved in the sea water, and the magnesium oxide remains in suspension until filtered out. This is a purely British modification of the process. At one United States plant, where many millions of gallons of sea water a day are treated, precipitation is carried out with the aid of crushed oyster shells taken from the sea bed nearby. The shells are calcined into lime.

Britain will never again have to look to other countries for magnesium. When the demand for the aircraft industry falls, the magnesium surplus will undoubtedly be used for making light alloys for a hundred domestic purposes—the shining metal sheets will probably play a great part in kitchen utensils of the future; they will give lightness with strength in motorcar coachwork

and will be extensively used in the manufacture of toys, bathroom fittings, and other appliances. The exact amount of magnesium being taken from the sea cannot now be given, but it runs into six figures a year, measured in tons.

Magnesium is not, of course, the only valuable chemical that is dissolved in sea water. In the future, greater use will be made of the sea as a source of bromine, potassium, and phosphorus. Bromine, present to the extent of one pound in every 4,000 gallons, has already been extensively obtained from the sea in the United States for the manufacture of "anti-knock" fuel of which the key substance is a lead compound dissolved in ethylene bromide. The extraction calls for very exact chemical measurements, and it is remarkable that these have been maintained in a plant handling 60,000,000 gallons of sea water a day.

The extraction of potash from the sea is possible but not economic in the present state of our knowledge. It is far more likely to be obtained, as we procure our common salt, by using sea water that has been concentrated by some freak of Nature. There are estimated to be 2,000 million tons of potash in the Dead Sea, and the chemical is easily obtained by evaporation. The amount of potash in the water is kept more or less constant by the rivers flowing into it.

Copper, iodine, arsenic, and gold are some of the other elements present in sea water in minute quantities. The iodine used to be extracted from seaweed, but other sources now make this uneconomical. Although gold is present only to the extent of one part in 1,000 millions, the amount of gold in the oceans greatly exceeds that ever taken from the earth in the whole history of man. So far, no good process of extraction has been discovered, although a large number have been tried. It is possible that electrical methods may succeed, and that the ship of the future, towing a gold extracting device behind it, will literally be able to "pay its way"! The only difficulty seems to be that once this was accomplished, gold would immediately lose all value as a monetary symbol. Perhaps this will not cause any regret among the scientific people of the future!—A. M. Low, British Consulting Engineer.

BOOK REVIEWS

WOODS HOLE

The Woods Hole Marine Biological Laboratory.
Frank R. Lillie. 284 pp. Illus. 1944. \$4.00.
University of Chicago Press.

A RICH source of historic and biological information has been made available in this book. The author, Dr. Frank R. Lillie, in collaboration with Prof. E. G. Conklin and other noted biologists has brought together a surprisingly complete and interesting account of the early efforts to establish a marine biological institution devoted to education and research.

The generous interwoven references to the seaside laboratory founded in 1873 on Penikese Island in Buzzards Bay by Louis Agassiz, noted American pioneer in the study of plants and animals as living entities in their natural habitats, to the Naples Zoological Station in Italy, and to other American and European stations, provide an illuminating story of the origin and development of institutions devoted to the study of marine biological problems.

This volume is outstanding in value because of the succinct review of progress in America of research and educational work in the important field of marine biology and the development of fundamental policies and practices vital to the success of other research and educational institutions. Emphasis is rightly placed on the importance of administration by competent scientists and on reasonable freedom in research procedures in solving biological problems.

From personal experience, the reviewer can attest to the stimulating and helpful influence of the formal and informal activities and relationships at this laboratory that have been so fittingly presented. While a university student assigned to the Bureau of Fisheries Station at Woods Hole, many courtesies were extended to him through invitations to attend special lectures at the laboratory and to participate in field trips. The informal contacts at the "mess," which was shared with the fisheries men, and on the bathing beaches and athletic fields were valuable features of the laboratory life. Later study at the Naples Station and many years spent in educational work and in conducting

and directing biological research in state and federal departments afforded the reviewer opportunity to continue acquaintance with the outstanding leaders of research and educational work who had been co-workers at Woods Hole. Pertinent, indeed, is the remark that "The influence of this laboratory in promoting peaceful co-operation in biology is one of its major by-products."

Marine organisms provide exceptionally favorable conditions for study of life histories and environmental relationships. This fact, coupled with the characteristic freedom of investigators in selecting their problems and techniques employed in their solution, accounts in part for the broad fields covered in published reports of results of investigations. The period of time covered by the work of this laboratory has been a fruitful one in American biological research. Investigators at the laboratory at Woods Hole not only have kept pace with the rapidly developing and diverse fields but have taken dominant positions of leadership. This is strikingly apparent as one reviews with Dr. Lillie the progress made over the years. The influence of Agassiz in stressing the importance of intensive study of living organisms in relation to their environment persisted.

Beginning in the familiar basic fields of classification and morphology, under the stimulus of the new approach, expansion into other fields advanced rapidly, yielding new and unexpected results of far-reaching significance. Studies in metamerism developed new interpretations of neuromuscular and sensory relationships and functions. The abundance and variety of reproductive processes in marine organisms led to crucial studies in embryology. Critical analyses of cell structure and cleavage procedures by workers at Woods Hole resulted in discarding or sharply modifying previously held concepts and in development of a vast new field of research and interpretation of sex phenomena, including the highly significant behavior of the chromosomes.

These investigations laid the foundations for the remarkable progress made by students at this laboratory in the fields of genetics and evolution, in general and experi-

mental physiology, and in physicochemical interpretations of vital processes and behavior of organisms. Results of these biological investigations have had a profound influence in the development of scientific medicine and medical research and education.

Brief biographical sketches of four of the outstanding leaders in the development of this laboratory and its work add an interesting human touch to the closing features of the volume. A delightful account of the community life at Woods Hole and a brief résumé of the origin and work of the closely associated Woods Hole Oceanographic Institution and of the extent to which co-operation of many federal agencies and educational institutions throughout the United States has been enlisted bring the volume to a fitting close. Helpful appendices and a well-planned index add greatly to its usefulness for reference purposes.—W. B. BELL.

PLANT GEOGRAPHY

Foundations of Plant Geography. Stanley A. Cain. xiv + 556 pp. Illus. 1944. \$5.00. Harper & Brothers, New York and London.

THIS volume, as the title implies, is not a textbook of plant geography but rather a broad inquiry into the basis of that science. That it is a much-needed volume goes without saying, for too much has been published on the subject without a clear understanding of basic principles on the part of certain authors. It is a very excellent example of a case where an individual has had the initiative and, through his own work and his remarkably wide study of the writings of specialists, the ability to make mental excursions into fields far beyond the scope of his own specialty and to synthesize conclusions from a wide variety of special fields. While it is true that in some cases a mental excursionist may sometimes draw conclusions that a specialist might not consider to be warranted, this is no reason why such excursions should not be undertaken. Too often the specialist working within a strictly limited field may draw only partial conclusions, quite missing certain wider implications because of his lack of knowledge of, or lack of interest in, the wider aspects of the subject.

The need is very great for just this type

of work, for in it the author has assembled a remarkably wide range of data, quoting this author's conclusions here and that author's conclusions there; yet he has had the courage of his convictions, and when he has disagreed with certain conclusions, for reasons that have appeared justifiable to himself, he has not hesitated to say so. And yet the author would be the last to claim that his own conclusions are always correct, or that the data cited to bring out certain points are always the best published examples. Clearly this volume does not fall in the category of an uninspired text, prepared just to make another volume, for it is a work that can be studied to advantage by specialists in a wide variety of subjects, ranging from taxonomy to genetics, from paleobotany to polyploidy, and from the nature of species to endemism. It is a work that should be read and digested by all professional botanists no matter what their special fields may be, and above all, one that should be intensively studied by all advanced students in botany, again, no matter what their thesis subject may be.

The volume is divided into five parts, the first consisting of a treatment of plant geography as a borderline science and an analysis of previously proposed principles. Part two, Paleogeography, eight chapters, is devoted to various aspects of paleobotany as applied to modern aspects of plant geography. Part three, entitled Aerogeography, ten chapters, involves discussions of such diverse subjects as concepts of area, dispersal and migration, criteria for determining centers of origin, endemism, senescence, discontinuous distribution, vicarious forms, polytypy and polyphylysis, and the theory of differentiation in relation to the science of area. Part four, Evolution and Plant Geography, four chapters, involves a consideration of the nature of species, isolation, causes of species stability, and the rate of evolution and speciation. Part five, five chapters, is entitled Significance of Polyploidy in Plant Geography, involving a discussion of various aspects of polyploidy.

The extraordinarily wide reading prosecuted by the author in connection with the preparation of this work is evidenced by the carefully prepared and critically checked terminal bibliography, consisting of 720

titles, literally from the published literature of the world. Acknowledgment is made to a long list of individuals who assisted in one way or another or who read portions of the manuscript, but the author remarks that by no means all who have read parts of the manuscript will be in total agreement with the final product.

Many who read and study this volume will doubtless recall various published items that may better illustrate certain points than do the cases cited. Some will note minor errors of one type or another. Others may passively or actively disagree with certain conclusions. But regardless of any criticism, the fair-minded individual can but admit that the author has performed a real service for botany *sensu latiore* in bringing together from the remarkably widely scattered literature, a general synthesis of the basis of our modern concepts of plant geography. Were I to select any single aspect of the work for criticism, it would be what appears to me to be an undue use of highly technical terms, a factor that seems to be particularly characteristic of plant ecology, and one that undoubtedly has had a retarding effect on the development of this field of modern botany. True, in the modern science of genetics, a wide range of highly technical terms have been devised within the present century, but as genetics has fallen in the "required" category of so many institutions, its special technical terms are now very widely accepted and in general are thoroughly understood by trained botanists and by graduate students. Plant ecology and plant geography being collateral subjects, of much interest but not so basic as genetics in our present scheme of things, are in general not required subjects, but are electives, and so attract a smaller number of students. The net result is that the complex terminology that has been developed by certain schools of ecology contain an extraordinary number of highly technical and limited terms. From the following list, selected more or less at random, how many general readers or trained botanists for that matter, could define offhand such terms as anemochore, autecology, chorology, eline, clisere, commiscuum, ecesis, epizoochore, geosere, hydrochore, isoflors, migrule, paedomorphosis, phylad, phytocoenosis, poly-

chronism, propagule, refugium, sere, soma, sympatric, synusia, and xerochase? In the work under consideration these and many other highly technical terms are used, and possibly their use in a text of this type is unavoidable; this is especially true when such highly technical terms appear in quoted passages, for then there is no way of avoiding them. Clearly, technical terms that narrowly define certain concepts are needed in special sciences, but nevertheless one cannot escape the conviction that in some sciences the art of coining such terms has been carried too far. However, in this case any such criticism as that above indicated is a very minor matter as the volume is supplied with an excellent and concise glossary, pages 474-490, in which all technical terms used in the work are clearly defined.

A sense of humor is evident in certain cases, such as the author's comment on his nonacceptance of the Neo-Lamarkian concepts of one author, and especially in his quoted passage regarding the Lower Mississippi River Delta, on the basis of the plethora of new species of *Iris* described from there in 1931, being the "Iris center of the universe," and Cooper's exceedingly naïve explanation of this phenomenon, characterized as the "flotsam and jetsam theory" and which "needs no further comment because of its patent ecological absurdity."—E. D. MERRILL.

FORESTRY ON PRIVATE LANDS

Forestry on Private Lands in the United States. Clarence F. Kerstian. 234 pp. Illus. 1944. \$1.50 cloth; \$1.00 paper. Duke University, Durham, N. C.

In 1942 the author, who is dean of the School of Forestry, Duke University, and a well-known silviculturist, made a study at the request of the National Lumber Manufacturers Association of the application of forestry practices on privately owned forest lands in the United States. Because of conflicting statements in recent years by foresters themselves about the progress of private forestry, with resultant confusion in the minds of the general public, this book is important and timely as an appraisal of past accomplishment and as a blueprint of future needs.

Perhaps America's most valuable renewable natural resource, important in peace and essential strategically in war, forests were wastefully exploited, cut, and burned for nearly three hundred years before organized public opinion demanded protection from fire and the setting aside of reserves such as national and state forests. At the turn of the century a few schools of collegiate grade began offering technical courses in forestry, and a body of professional knowledge was laboriously created.

An intelligent observer of the forest conservation movement will perceive that whereas forest exploitation has existed as an economic way of life for three centuries, forestry as a profession has existed for less than half a century. Notwithstanding this disparity, out of 345 million acres of privately owned forest land in 37 states, 29 million acres are under sustained-yield management for forest products industries; 72 million acres are under continuous production but not under sustained yield; and 207 million acres are restocked or potentially productive. A remainder of 37 million acres is in nonproductive condition.

Prior to the war nearly 1,000 foresters were employed by the forest products industries in forest land management, or a ratio of 151,000 acres to each forester. Dr. Korstian points out that on a basis of 25,000 acres to each forester, a ratio which he apparently believes is needed, at least 4,000 foresters should be engaged in the management of industrial forest holdings.

To determine the measures needed to remedy the private forestry situation, the author sampled facts and informed opinion in eight selected states representative of the nation's four important forest regions, and then evaluated the suggestions and information obtained.

As was to be expected, he reports that "the first basic requirement for the practice of forestry, whether on public or private forest lands" is adequate fire prevention and control. Satisfactory protection he found especially lacking in the South. He recommends, as a supplement to adequate protection, public control of public use of private forest lands.

In the public programs of education and

co-operative assistance to private owners he finds much to commend, particularly extension activities, farm forest co-operatives, and co-operative research. But he warns against the tendency for the number of federal agencies engaged in this work to increase and makes a convincing plea for co-ordination of their activities.

The establishment of sustained-yield management units is recommended where heavily capitalized industries with communities dependent on them must obtain their wood supply from publicly and privately owned lands.

Although the author strongly recommends equitable taxation as an inducement for private ownership to practice forestry, he finds that taxation is more important as a factor in preventing reforestation than as a cause of clear cutting and forest liquidation.

Dr. Korstian discusses at length what is perhaps the most controversial issue involved in the problem of keeping private forest lands continuously productive—public control of cutting practices. In his opinion some form of public control appears inevitable. His conclusion is:

The regulation of forest cutting practices should be enforced by the states as soon as adequate control of forest fires has been provided. . . . Lack of adequate fire protection in a state, however, should not forestall the formulation of a code of desirable forestry practices for that state, so that the code may have prompt legislative approval and administrative enforcement upon the attainment of adequate fire control.

Finally, he calls for more aggressive programs by national and regional forest products industries associations to provide for technical assistance in the practice of forestry by industry, for encouragement by industry of legislation for forest protection and production, for support by industry of state forestry agencies in developing cutting practices, and for increased research by industry in management, utilization, and marketing.

An appendix includes a brief glossary of technical terms and a draft of a model bill for state control of private cutting practices. The bibliography will be found helpful. The photographic illustrations have been well selected and clearly reproduced.

The book is an important addition to the literature of forestry because it promotes

better understanding of private forest conditions and the measures needed to make private forest lands productive.—HENRY CLAPPER.

AGRICULTURAL CHEMISTRY

A Source Book of Agricultural Chemistry. Charles A. Browne. 290 pp. Illus. 1944. \$5.00. Chronica Botanica Co., Waltham, Mass.

THIS book by Dr. Browne, who is eminent both as a chemist and as a historian of science, constitutes a most valuable contribution to the general field of science history. Its value lies not so much in the thoroughness with which the evolution of this relatively new subject of agricultural chemistry is dissected and traced but in the mode of approach, which may well serve as a model to future scholars in the history of science.

The work is called a source book rather than a history because the work of each investigator discussed is represented by poignant and characteristic quotations. This is a useful practice, unfortunately too often neglected. Nothing can replace the flavor, style, and logic of an original text. No description of Paracelsus, for example, can convey to the reader the nature of his originality, his flamboyance, his prejudices, egotism, and other idiosyncracies as much as a good citation from his works.

Yet Dr. Browne does not fail to present helpful evaluations of the philosophers and scientists who qualify as agricultural chemists. These are cited in historical sequence from Thales (about 640–546 B. C.) to Liebig (1803–1873). His comments are lucid but terse; critical yet unobstructed by dogma and the all-too-common will to judge and condemn. Each author is placed in proper perspective with respect to the prevailing beliefs of his period as well as to the course of development of agricultural knowledge.

I believe the following quotation from Dr. Browne's text (page 92) is typical of his approach, his historical perspicacity, and clarity of expression:

JETHRO TULL (1674–1740):—As the chemist reviews the various theories of plant nutrition which had been proposed up to the time of the publication of Hales' "Vegetables Staticks" he will note that different investigators emphasized some one particular element or factor as of dominant importance. Van Helmont, Bacon, Boyle, and others selected

water as the chief element from which crops derived their nourishment; Mayow emphasized the importance of the fire-element or phlogiston; Glauber and many others of his persuasion attributed everything to nitre; another smaller group, of which Woodward was the precursor, called attention to the needs of earth. The leading advocate of the doctrine that earth was the chief factor in nutrition of crops was the celebrated English agricultural writer and farmer, Jethro Tull.

The author follows these devious routes of the human mind in its search for knowledge and truth. He calls attention to many contributors and contributions that had been neglected by previous historians and corrects past disregard of some investigators and the overstressing of the significance of others. The effect of the book is much like that of a novel or drama in which the plot is logically and absorbingly developed. And indeed a drama it is with mankind as the hero working through brilliant minds that spring up here and there ready to detect problems and grapple with them in a timeless strife; wading in error for centuries and yet clearing up one truth here and another there, until in the course of one or two thousand years a mighty edifice of knowledge stands erected, ready for further progress.

To my mind the book shows how much more can be learned from a history of a specific scientific pursuit than from a general account covering all sciences. From reading a history such as this, one cannot fail to get a clear conception of the evolution of agricultural chemistry, its founders and builders, their mode of approach, obstacles, and achievements. The reader invariably gets a clear idea of what a hard struggle progress entails. In the words of Dr. Browne (page 180):

As the student reviews the developments in the history of agricultural chemical science, he is repeatedly impressed by the slowness and apparent reluctance of investigators to revise their opinions even long after the time when the unreliability of their views had been demonstrated and exposed.

Perhaps few general histories of science come sufficiently close to historical grassroots to actually be in a position of demonstrating the true educational and intellectual value of science history. The volume under review accomplishes precisely that to a degree seldom equalled.

Besides full accounts of the views and

experiments in the field of agricultural chemistry and the telling quotations already referred to, the *Source Book* is also replete with interesting reproductions of diagrams, tables, apparatus, and title pages of the original works cited. After the discussion of each scientist, his relevant writings are cited and often a full list of their editions is given. The book is a remarkable achievement and a beacon for future historians.—MARK GRAUBARD.

PRACTICAL PLANT ANATOMY

Practical Plant Anatomy. A. S. Foster. 155 pp. 1942. \$2.50. D. Van Nostrand Company, Inc., New York.

SINCE the time of De Bary a wealth of anatomical theories and information has accumulated, resulting often in confusion of the beginner in the study of plant anatomy, and even in some seasoned specialists of the field. It is heartening to learn of a new anatomical book that will greatly aid in reducing the confusion and will narrow the hiatus between theory and practice in the teaching of plant anatomy. Foster's *Practical Plant Anatomy* fills a definite need because no other educationally sound and up-to-date guide on this subject has so far been published. However, this book is in no way a substitute for any one of the standard texts in plant anatomy, or for collateral reading in selected, modern anatomical literature. This work will articulate the practical study of laboratory material with selected modern interpretation and theory. A realistic foundation in plant anatomy is not obtained through lectures on theories but rather by laboratory experience. It is necessary for most of us to *see and work with the actual material*. In addition Foster's book presents the best fundamental material on apical meristems, not sufficiently covered by available texts. This last point alone would justify its publication.

The book consists of fourteen exercises.

Each exercise is initiated with an introduction that briefly but clearly summarizes the present level of interpretation of the subject. This should aid the student to critically evaluate theory in relation to practice. The value of the book might have been enhanced if the writer, instead of explaining everything to the student, had introduced problem questions and had encouraged the drawing of inferences. Through such problems a student attains a new freedom and confidence in his own ability to observe.

Materials suggested under each exercise are usually readily available to most teachers of the subject. References are often made to plants of immediate economic importance. At the end of each exercise several references are suggested for collateral reading. In these, as well as through the text portion, textbooks are occasionally cited with reference to pages.

In the exercise on the classification of cell types, tissues, and tissue systems a discussion is presented dealing with the classification systems of Sachs, Haberlandt, and Eames and MacDaniels. This discussion is followed by a tabular summary of main cell types in seed plants. This method of presentation should be quite useful to students.

The exercises are presented in the following order, under the headings: The Protoplast; The Cell Wall; Meristems; Problems in the Classification of Cell Types, Tissues and Tissue Systems in Vascular Plants; The Epidermis; Parenchyma Cells; Collenchyma Cells; Sclereides; Fibers; Tracheary Elements; Sieve-tube Elements; The Stem; The Leaf; and the Root. A short appendix contains some of the more useful methods of microtechnic with application to anatomical problems. A complete index covers thirteen pages.

This new guide book to plant anatomy is a very definite contribution to the subject, and will find a definite place in college and university laboratories.—GLENN W. BLAYDES.

COMMENTS AND CRITICISMS

An Obstacle to a Science of Education

An examination of the literature dealing with the aims, aspirations, methods, and philosophy of science shows an increasing number of individuals embracing the hypothesis that an application of the methods of science to the study of society will result in an increasing amelioration of the ills of society. Possibly some workers consider this no longer a hypothesis but conclude that it has been demonstrated—in certain areas in economics, sociology (especially in population studies), industrial psychology, and in learning—to mention but a few fields. It is perhaps on this basis, having seen the result of the application of science to problems of society, that C. I. Glicksberg writes (*THE SCIENTIFIC MONTHLY*, July 1944, p. 20):

"All science teaching, particularly on the secondary school level, must be 'impure,' applied, humanly practical and significant. It should be concerned not only with machines, amperes, atoms, motion, light, heat, electricity, and chemical formulas; its scope is the entire universe, all of human life.

"It includes such unorthodox and relatively unexplored subjects as economics, politics, human nature, love, hate, war, dreams, myths, religions, attitudes, opinions, beliefs, values, truths. All these fall within the spacious province of science."

The superb enthusiasm of Dr. Glicksberg and his hopes and desires in the significant area of education strike a resonant chord in the present writer, who has the same hopes and desires. But Dr. Glicksberg's fine article contains, at once, the elements that may tend to bring education toward the status of a science and the elements that are neutralizing this advance and are maintaining education as a field where authority, argument, wishful thinking, and armchair philosophies reign. If superstition, authority, argument, and scientific method are the phases through which any given subject progresses toward the status of a science, then education is imprisoned in its largest segments by authority and argument. And if one is to define superstition as belief for which evidence is lacking, then, in the writer's opinion, some of the theories of education are based firmly on superstition. This is especially true of the theories concerning classroom practice. On the other hand, a strong and persistent movement has shown itself in the attempt to place education firmly on a wide base of data gathered experimentally.

Dr. Glicksberg has done science education a service in stating his point of view, which he also generously admits has been stated, perhaps in different form, by Pearson, Bernal, Hogben, Dewey, Korzybski,

Levy, Crowther, and others. The social responsibilities of the science teacher have been emphasized throughout the teachers' colleges, particularly by Powers, of Teachers College, Columbia University. At the same time, Dr. Glicksberg has allowed himself the luxury of arguing the cause of science without restricting himself to the evidence; in that sense, the cause of science education has not been served. A few examples should clarify this point. Dr. Glicksberg states:

"To be successful, such a course would have to deal with problems that challenge the interest of the young. History teachers, English teachers, and science teachers could join forces in helping students to undertake simple research in some such problems as: What is intelligence? Is there a close correlation between intelligence and race? Is character the result of heredity and environment, or both, and in what proportions? What characteristics are inherited and what acquired? Why do many people act irrationally? How does the human mind work? What is hypnotism? Are people highly suggestible? How is this used by business and political interests to influence the minds of men? Is mental telepathy scientifically confirmed? Is it possible to foretell the future? Many of these problems no doubt will prove highly difficult, perhaps insoluble, but it is a *profitable experience for the young to tackle them even if in the end they feel baffled*. For that is a good way of putting the scientific method actually to work and testing its range of operational validity."

What is the evidence for the statement I have italicized above? Possibly a suitably devised experiment would show that the young do not profit from tackling problems unless a reasonable amount of scientifically gathered data is available to guide them in their critical thinking.

Again, Dr. Glicksberg states:

"This is but another way of saying that departmentalized instruction, which attempts to feed students knowledge regardless of their interests or needs, is ineffectual. Nothing is more potent in one's own education than his factually-founded realization of the inexorable nature of scientific occurrences."

What experiment can be cited; what data exist to support the statement that such teaching "is ineffectual"? The second sentence of this statement is especially strong; the use of the words "nothing is more potent" is to be questioned in the light of the fact that no evidence or a statement summarizing the evidence is given supporting this assertion.

Further, Dr. Glicksberg states: "It is in the schools that the battle of science will be fought—

and lost or won." This is a conclusion that seemingly lacks data to support it. It is evident that a youngster does not get all his education in school; as a matter of fact, he spends the greater part of his time out of it.

Of course, one might contend that Dr. Glicksberg's paper presents a point of view and therefore is not primarily concerned with evidence. The question of critical importance is this: Should not individuals who believe in the efficiency of the scientific method, who believe it to be the one method whose application will solve many of the world's ills, restrict themselves to conclusions that conform to existing evidence?

It would have been of great value if Dr. Glicksberg had been able to show that students who have had a type of education that has forced them to examine social problems scientifically are, in comparison with the control group, superior in dealing with such problems.

Others also have hastened to confuse hypotheses with conclusions. One high-school text in physics may be cited—*Physics of Today*, by Clark, Gorton, and Sears. The book is a mass of data; it holds itself strictly to conclusions based on those data. But after an introduction in which a simple experiment is given, designed to show the difference between jumping to conclusions and testing the hypothesis, the authors state: "We study science to help us think correctly instead of jumping to conclusions. By the time you have finished your study of physics you may be able to reason as well as you can read." What is the evidence that individuals who finish a study in physics may be improved in their ability to reason as well as they can read? What is the relationship between reading score and successful reasoning in physics in the first place? Or is this statement merely a residue of the dogma of formal discipline?

It would be a very easy task to show that teachers who are writing articles in chemistry, biology, physics, and other sciences are not adhering to the practice of the scientific method they bring to their students. In short, on the basis of all his readings in education and of his observations at education seminars this writer is forced to conclude that educators are not always ready to discard beliefs for which little or no data are available. Surprising or not, the same conclusions may be drawn from observations in science education, where, presumably, there has been more opportunity to deal with the philosophy and methods of science.

An acceptable working hypothesis might be one which supposes that as workers in the field of education adopt the rigorous methods of science, so much nearer shall we be to the realization of a science of education.

Sometimes, as one reads material in education he finds that the word "reason" is used synonymously

with "scientific method." Somehow or other it is supposed that young people who reason through their problems will be using the scientific method. The latter is so closely identified with reason that many educators forget that science reasons with the facts obtained through an experiential method. A reasoned statement without data is a "hypothesis." With the data to support it, it reaches the status of a conclusion. This point may bear some discussion.

After Pasteur's monumental investigations that led to the germ theory of disease, reasoning alone might have ascribed the cause of such nutritional deficiency diseases as pellagra, scurvy, and beriberi to some germ, but investigation (reasoning with data) showed the chemical nature of these diseases. Reasoning as such found that two balls of different weights would fall to the ground at speeds related to their weights, but Galileo's experiments negated this reasoning. The Roux-Weismann theory of mosaic development was reasoned from the presumed behavior of the chromosomes, but investigation did not support it. It was reasonable to assume that the orbits of the planets were circular until Tycho Brahe and Kepler reasoned differently from investigations and found them to be ellipses.

Is it possible to say that at present armchair reasoning about the problems of education can produce hypotheses and not solutions because data, scientifically observed, are lacking? And what progress can be made by basing one hypothesis on many others? This practice may result in injury to the very youngsters whose development we hold so sacred.

But we must not be too pessimistic. Science education, whether a result of the efforts of the school or not, has not been a complete failure. Witness one of our ordinary citizens who knows something of the way in which an automobile works. His car stops because of some faulty operation. Notice how at once he checks his different hypotheses: he checks his spark plugs, his fan, his water, his gas, before he comes to a conclusion.

We want to, and we must, go further. We should like every citizen to be in a small measure his own sociologist, his own economist, his own nurse, his own victory gardener, his own anthropologist. Our citizen, in the words of Hogben, should have a basis for the rational judgment about the things that affect his social welfare.

Very well. It is clear that science educators, who have seen what the scientific method can do when it is applied to cracking of petroleum, to the conquest of smallpox and diphtheria, to the study of isotopes, to the study of varieties of *Homo sapiens*, are bound to apply this scientific method to a study of how best to educate young people so that these young people can apply these methods to a solution of their personal problems.

Time is fleeting. We should begin at once to verify

scientifically those hypotheses that are on rampage through works in education and also, strangely enough, are finding a resting place in works in science education.—PAUL F. BRANDWEIN, Teachers College, Columbia University.

Leishmaniasis in Texas

The paper on Cutaneous Leishmaniasis in Mexico, by Señor Enrique Beltrán in the August issue, was very interesting to me. It should be noted however that in the medical literature generally the American form of Leishmaniasis is referred to as "Mucocutaneous" in contradistinction to Old World Cutaneous Leishmaniasis.

We have recently seen a case of Mucocutaneous Leishmaniasis here in Texas in a patient who was born here and had never been out of this country, in fact has never been outside of a range of three counties in this region. This is apparently the first case in this country occurring in a person who has never been in any foreign country and we are reporting it as such.

No doubt other cases have occurred in this region, and more cases will be identified if we keep this condition in mind and look for it.—JOHN F. PILCHER, M.D.

Culture

The recent article in the Monthly on "Science in French Canada" was a most interesting indictment of educational methods in American technical schools. There are numerous people who have received a so-called technical education who are finding a lack of general culture a decided handicap in their daily lives. Could not some authority on humanism give us an article outlining a method and bibliography with which we could overcome this handicap by extensive reading? I find the selection of literature for this purpose by haphazard methods to be highly unsatisfactory.—ROBERT E. LENZ.

We make the modest suggestion that those who take *Science* should also take and read THE SCIENTIFIC MONTHLY.—ED.

Duelism

If, to quote from the comment of Anna Rosenberg on "Philosophy and the Supernatural" in the November Monthly, "empiricism, for the scientific mind, is the most acceptable brand of philosophic thought," and if with her we also "feel that philosophy has outlived its usefulness to man's efforts at orientation," it would seem to follow that scientific Empiricism as a brand of philosophy must have "outlived its usefulness," not because it serves in orienting this "scientific" mind to reality, but because it does not so serve, and because that peculiar

mind, being uninterested in such orientation, finds this brand "most acceptable" precisely because it is such as avoids, by making a shibboleth of "common sense," any attempt at orientation.—ALDEN A. POTTER.

Science and Social Wisdom

I have read with much interest and appreciation your [Dr. Brody's] article on "Science and Social Wisdom" in the current issue of THE SCIENTIFIC MONTHLY. As one who has been working in the field of religion from the functional approach, I find myself in hearty agreement with your point of view and your conclusions. I am firmly convinced that many of the most significant contributions to religious thinking will come from the field of science rather than from the closed system of theological speculation.—W. C. BOWER.

You [Dr. Brody] have approached the chief problem of the age from a new angle—new to me at least—and the result is illuminating. You have given a clear-cut picture of the conditions forming our present problem. It would be fine if scientists adopted the policy you mention on your last page. I'm not very hopeful of its speedy adoption. But as I believe the first step to solving a problem is to have a definite idea of its conditions and constitution, I am sure you have in any case taken a step forward.—JOHN DEWEY.

I hope that I will not be the only person to write you [Dr. Brody] a letter protesting your self-appointment to the Chair of Instruction on Moral Theology to the scientific world. As a scientist, you no doubt realize that few people would listen to the ordinary preacher who would dare to write an article on science in a reputable scientific magazine. In fact, if the preacher's ideas on science were as groping and inexact as are your ideas on moral theology and its relationship to the social order, I sincerely doubt whether the scientific magazine would accept his article.—MATTHEW A. MCKAVITT.

Let me congratulate you upon publishing the article on "Science and Social Wisdom" by Samuel Brody, a former colleague of mine at the University of Missouri. We need such articles from scientific men very much. I fear, however, that there is no hope that the Association will carry out Professor Brody's suggestion of a committee to study such problems as he outlined. Neither is there any hope that professional sociologists will take up social problems of this sort, because that would make them "Social Philosophers." Can you think of a worse name for scientific men?—CHARLES A. ELLWOOD.

Carter, not Carver

It is painful to a bibliographer to see the accom-

plished and learned scholar Thomas Francis Carter referred to not once but three separate times [in "An Arabic Block Print"] as Carver, December, 1944, page 473. There might follow Newson, Fibbs, Ein-

skein, Volsclair, and other horrors ad infinitum. However, it is pleasant to see a bibliotypographic article in THE SCIENTIFIC MONTHLY. The Monthly's arrival is ever welcome.—S. R. SHAPIRO.

THE BROWNSTONE TOWER



THE SCIENTIFIC MONTHLY differs from most nontechnical magazines in that nearly every reader is an actual or potential contributor. Therefore it seems to the editor that the readers of the MONTHLY might like to know more than they now do about

how it functions, and so we present "The Brownstone Tower." It is not promised as a permanent column of the MONTHLY, but it may appear each month as long as it seems to serve a useful purpose.

The editor chooses to call his column "The Brownstone Tower" because his office is situated in the largest tower of the old brownstone Smithsonian Institution Building. The above sketch, which was provided through the courtesy of the Smithsonian Institution, depicts the Tower. Notice a circular area about halfway up. It is pierced by a central hole and four quatrefoils, and around the periphery are Roman numerals. Evidently it is a clock face, but we are told that a clock was never installed. The small, low-ceilinged room behind the clock face is the editorial office of THE SCIENTIFIC MONTHLY, a unique office that is an oasis of isolation and quietness in the midst of bustling Washington.

Occasionally a visitor finds his way to the office. To reach us he takes the automatic elevator at the left of the main entrance of the building and ascends to the fourth floor. He then traverses the corridor before him and turns right into the Tower where he takes a smaller automatic elevator. Pressing button number eight, he will arrive at the editorial office, which is the eighth floor. He needs only to step out of the elevator to meet the editor and his able assistant, Mrs. Mary Scovill, whose husband, Captain E. B. Scovill, Combat Engineers, is at the front in Germany. Our visitor will first be shown the view from the clear south window. Looking out this window, he will see the broad Potomac and

across the river, the National Airport at Gravelly Point. Through the quatrefoils of the west window he will glimpse the Washington Monument and the Lincoln Memorial and through the north window, the National Museum across the Mall. The east window is blocked by the elevator shaft.

Should the elevator break down during our visitor's stay, it would be quite embarrassing to us, if not to him, for he could not get out of the Tower unless he were willing to climb down a vertical steel ladder through trap doors. But if the elevator functions, as it usually does, he might be taken to the eleventh floor of the Tower, which is now occupied by Dr. C. G. Abbot, who recently retired as Secretary of the Smithsonian Institution. It is an appropriate room for Dr. Abbot for he is now nearer the sun, and from his office the view is unobstructed. If time permits, the visitor might be taken down to the offices of the A.A.A.S. on the third floor front of the main building where he might meet Dr. F. R. Moulton, the Permanent Secretary, and Mr. and Mrs. Sam Woodley, who, in addition to many other duties, take care of subscriptions and distribution of THE SCIENTIFIC MONTHLY. Should the visitor have any interest in advertising, he would be taken into the bowels of the building to the room known to us as "the dungeon" before it was refurbished for office use. There Mr. T. J. Christensen, the new Advertising Manager of *Science* and THE SCIENTIFIC MONTHLY, makes his headquarters with his assistant, Miss Ruth I. Filsinger.

It was Mr. Christensen who urged the editor to start this column. Of Danish ancestry, Mr. Christensen is a vigorous, enterprising young man, who comes to the Association from Columbus, Ohio, where he served in fact, though not in title, as assistant director of The Ohio State University Research Foundation. He holds the degree of Master of Business Administration from Northwestern University.

In subsequent issues the editor will discuss in this column the policies of the MONTHLY and the problems he encounters in the acquisition of manuscripts and their preparation for publication, and other subjects helpful to contributors.—Ed.